Hitachi Microcomputer Support Software

SuperH RISC Engine Assembler

User's Manual

HITACHI

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Preface

This manual describes the SuperH RISC Engine Assembler (hereafter referred to as the assembler), which supports development of programs for Hitachi SuperH RISC engine family (hereafter referred to as microprocessor).

This manual is organized as follows:

Overview:	Gives an overview of the functions of the assembler.
Programmer's Guide:	Describes the assembly language syntax and programming techniques.
User's Guide:	Describes the use (invocation) of the assembler program itself and the command line options.
Appendix:	Describes assembler limitations and error messages.

Read this manual and fully understand its mechanisim before use of the assembler.

For information concerning the related hardware and software, read the corresponding manuals and understand their mechanisims before use.

Notes:

- The following symbols have special meanings in this manual.

<item>:	<specification item>
:	Blank space(s) or tab(s)
%:	The OS prompt (indicates the input waiting state)
(RET):	Press the Return (Enter) key.
... :	The preceding item can be repeated.
[ ]:	The enclosed item is optional (i.e., can be omitted.)

- Numbers are written as follows in this manual.

Binary:	A prefix of "B'" is used.
Octal:	A prefix of "Q'" is used.
Decimal:	A prefix of "D'" is used.
Hexadecimal:	A prefix of "H'" is used.

However, when there is no specification, the number without a prefix is decimal.

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Overview

Section 1 Overview

The assembler converts source programs written in assembly language into a format that can be handled by microprocessors, and outputs the result as an object module. Also, the results of the assembly processing are output as an assemble listing.

This assembler provides the following functions to support efficient program development:

- Assembler directives
  Give the assembler various instructions.
- File inclusion function
  Includes files into a source file.
- Conditional assembly function
  Selects source statements to be assembled or repeats assembly according to a specified condition.
- Macro function
  Gives a name to a sequence of statements and defines it as one instruction.
- Automatic literal pool generation function
  Interprets data transfer instructions MOV.W #imm, MOV.L #imm, and MOVA #imm that are not provided by the SuperH RISC engine family as extended instructions and expands them into microprocessor executable instructions and constant data (literals).
- Automatic repeat loop generation function
  Interprets instruction REPEAT that is not provided by the SH-DSP as an extended instruction and expands it into SH-DSP repeat loop instructions (LDRS, LDRE, and SETRC) that control the repeat loop characteristic of the SH-DSP.

Figure 1-1 shows the function of the assembler.

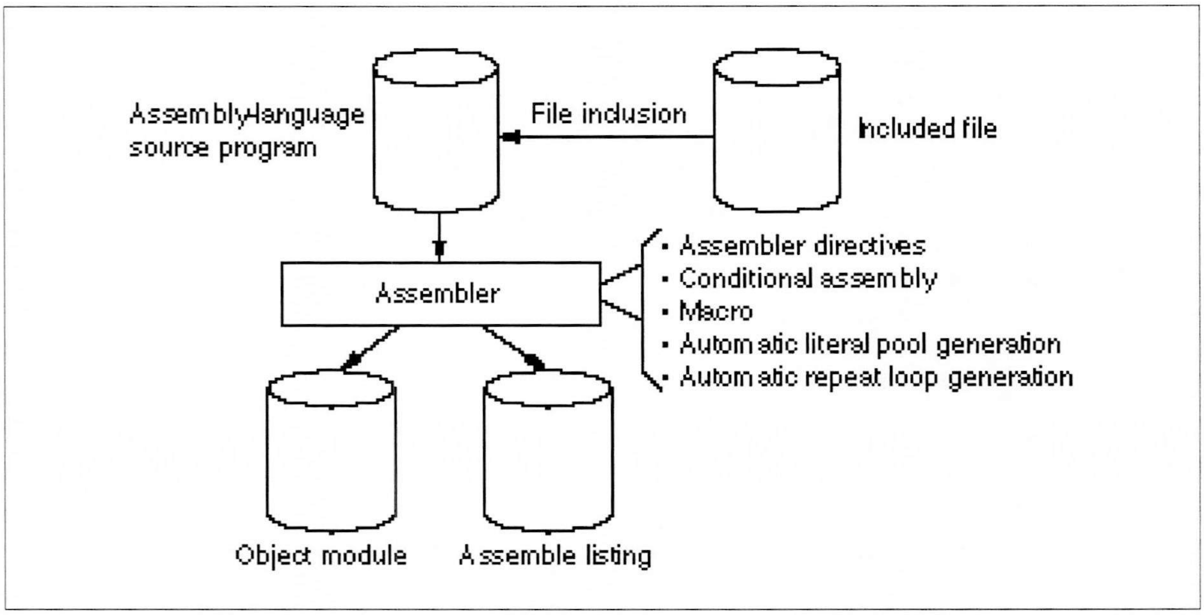


Figure 1-1 Function of the Assembler

Section 2 Relationships between the Software Development Support Tools

In addition to the assembler, software development support tools, such as the C/C++ compiler, linkage editor, librarian, object converter, and simulator/debugger are available for the SuperH RISC engine family.

These tools assist in the efficient development of application software.

Figure 2-1 shows the relationships between the software development support tools.

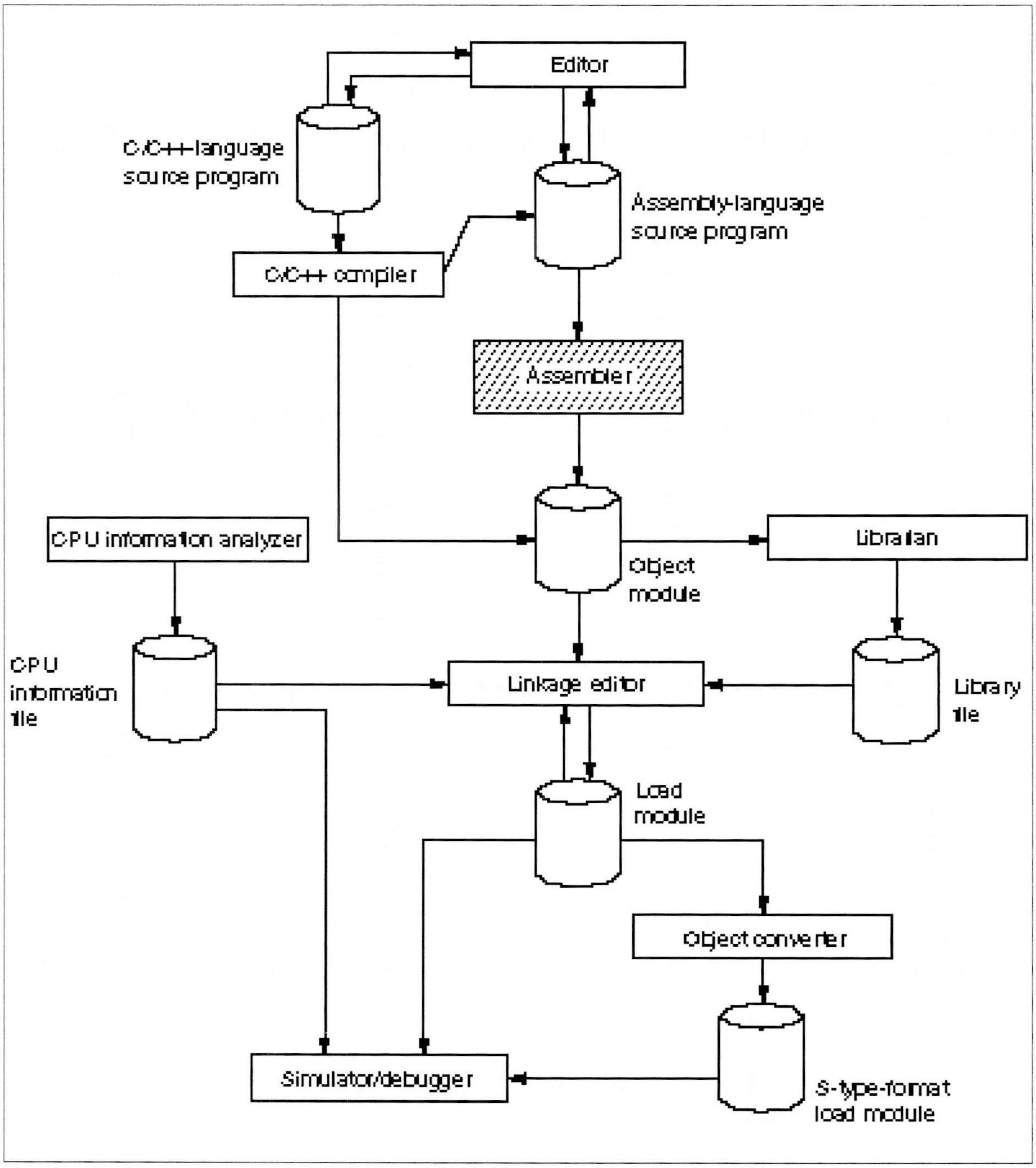


Figure 2-1 Relationships between the Software Development Support Tools

Supplement:

Use a general purpose editor (a text editor) to edit source programs.

The C/C++ compiler converts programs written in the C/C++ language into either object modules or assembly-language source programs.

The librarian converts object modules and relocatable load modules into library files. We recommend handling processing that is common to multiple programs as a library file. (This has several advantages, including allowing modules to be easily managed.)

The linkage editor links together object modules and library files to produce load modules (executable programs).

The object converter converts load modules into the S-type format. (The S-type format is a standard load module format.)

The simulator/debugger assists debugging microprocessor software.

Load modules created by this development support system can be input to several types of emulator. (Emulators are systems for debugging microprocessor system hardware and software.) Also, S-type-format load modules can be input into most EPROM programmers.

Programmer's Guide

Section 1 Program Elements

1.1 Source Statements

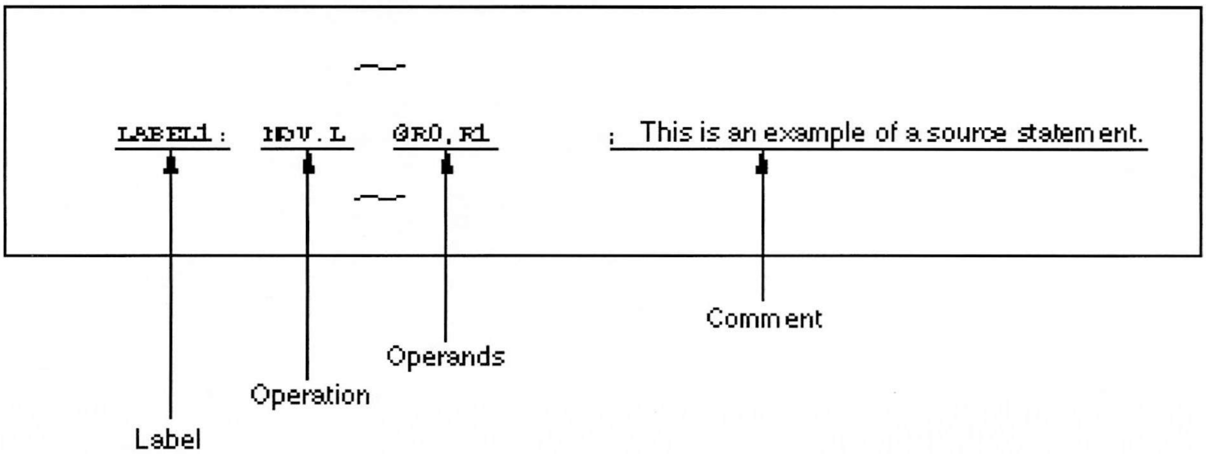
If source programs are compared to natural language writing, a source statement will correspond to "a sentence." The "words" that make up a source statement are reserved words and symbols.

1.1.1 Source Statement Structure

The following shows the structure of a source statement.

```
[<label>] [ <operation>[ <operand(s)>]] [<comment>]
```

Example:



(1) Label

A symbol or a local symbol is written as a tag attached to a source statement.

A symbol is a name defined by the programmer.

(2) Operation

The mnemonic of an executable instruction, an extended instruction, a DSP instruction, an assembler directive, or a directive statement is written as the operation.

Executable instructions must be microprocessor instructions.

Extended instructions are instructions that are expanded into executable instructions and constant data (literals) or several executable instructions. For details, refer to Programmer's Guide, 9, "Automatic Literal Pool Generation Function" and 10, "Automatic Repeat Loop Generation Function".

DSP instructions are instructions that control the DSP of the SH-DSP microprocessor. For details, refer to Programmer's Guide, 4, "DSP Instructions."

Assembler directives are instructions that give directions to the assembler.

Directive statements are used for file inclusion, conditional assembly, and macro functions. For details on each of these functions, refer to Programmer's Guide, 6, "File Inclusion Function", 7, "Conditional Assembly Function", or 8, "Macro Function".

(3) Operand

The object(s) of the operation's execution are written as the operand.

The number of operands and their types are determined by the operation. There are also operations which do not require any operands.

(4) Comment

Notes or explanations that make the program easier to understand are written as the comment.

1.1.2 Coding of Source Statements

Source statements are written using ASCII characters. Character strings and comments can include Japanese kana and kanji characters (shift JIS code or EUC code).

In principle, a single statement must be written on a single line. The maximum length of a line is 255 bytes.

(1) Coding of Label

The label is written as follows:

- Written starting in the first column,
  Or:
- Written with a colon (:) appended to the end of the label.

Examples:

```
LABEL1                              ; This label is written starting in the first column.
 LABEL2:                            ; This label is terminated with a colon.
------------------------------------------------------------------------
-
     LABEL3                         ; This label is regarded as an error by the assembler,
                                    ; since it is neither written starting in the first column
                                    ; nor terminated with a colon.
```

(2) Coding of Operation

The operation is written as follows:

- When there is no label:
  Written starting in the second or later column.
- When there is a label:
  Written after the label, separated by one or more spaces or tabs.

Examples:

```
          ADD     R0,R1       ; An example with no label.
LABEL1:   ADD     R1,R2       ; An example with a label.
```

CAUTION!

Since white spaces and tabs are ASCII characters, each space or tab requires a byte of storage.

(3) Coding of Operand

The operand is written following the operation field, separated by one or more spaces or tabs.

Examples:

```
        ADD      R0,R1        ; The ADD instruction takes two operands.
        SHAL     R1           ; The SHAL instruction takes one operand.
```

(4) Coding of Comment

The comment is written following a semicolon (;).

The assembler regards all characters from the semicolon to the end of the line as the comment.

Examples:

```
        ADD      R0,R1        ; Adds R0 to R1.
```

1.1.3 Coding of Source Statements across Multiple Lines

A single source statement can be written across several lines in the following situations:

- When the source statement is too long as a single statement.
- When it is desirable to attach a comment to each operand.

Write source statements across multiple lines using the following procedure.

1. Insert a new line after a comma that separates operands.
2. Insert a plus sign (+) in the first column of the new line.
3. Continue writing the source statement following the plus sign.

Spaces and tabs can be inserted following the plus sign.

Examples:

```
            .DATA.L    H'FFFF0000,
+                      H'FF00FF00,
+                      H'FFFFFFFF

; In this example, a single source statement is written across three lines.
```

A comment can be attached at the end of each line.

Examples:

```
            .DATA.L    H'FFFF0000,      ; Initial value 1.
+                      H'FF00FF00,      ; Initial value 2.
+                      H'FFFFFFFF       ; Initial value 3.

; In this example, a comment is attached to each operand.
```

1.2 Reserved Words

Reserved words are names that the assembler reserves as symbols with special meanings.

Register names, operators, and the location counter are used as reserved words. Reserved words are different depending on the CPU type. Refer to the programming manual of the CPU used, for details.

Reserved words must not be used as symbols.

- Register names: R0 to R15, FR0 to FR15, DR0 to DR14 (only even values), XD0 to XD14 (only even values), FV0 to FV12 (only multiples of four), R0_BANK to R7_BANK, SP, SR, GBR, VBR, MACH, MACL, PR, PC, SSR, SPC, FPUL, FPSCR, MOD, RE, RS, DSR, A0, A0G, A1, A1G, M0, M1, X0, X1, Y0, Y1, XMTRX, DBR, SGR
- Operators: STARTOF, SIZEOF, HIGH, LOW, HWORD, LWORD, $EVEN, $ODD, $EVEN2, $ODD2
- Location counter ($)

Note: R15 and SP indicate the same register.

Reference:

Operators	→	Programmer's Guide, 1.6.1, "Expression Elements"
Location counter	→	Programmer's Guide, 1.5, "Location Counter"
CPU type	→	Programmer's Guide, 5.2.1, "Target CPU Assembler Directive", .CPU
	→	User's Guide, 1.3, "SHCPU Environment Variable"
	→	User's Guide, 2.2.1, "Target CPU Command Line Option", –CPU
Symbols	→	Programmer's Guide, 1.3, "Symbols"

1.3 Symbols

1.3.1 Functions of Symbols

Symbols are names defined by the programmer, and perform the following functions.

- Address symbols .... Express data storage and branch destination addresses.
- Constant symbols .... Express constants.
- Aliases of register names...... Express general registers and floating-point registers.
- Section names .... Express section names. *

Note: A section is a part of the program, and the linkage editor regards it as a unit of processing.

The following shows examples of symbol usage.

Examples:

```
        ~
        BRA     SUB1         ; BRA is a branch instruction.
                             ; SUB1 is the address symbol of the destination.
        ~
SUB1:
        ~
--------------------------------------------------------------------------------
        ~
MAX:    .EQU    100          ; .EQU is an assembler directive that sets a value to a
                             ; symbol.
        MOV.B   #MAX,R0      ; MAX expresses the constant value 100.
        ~
--------------------------------------------------------------------------------
        ~
MIN:    .REG      R0         ; .REG is an assembler directive that defines a register
                             ; alias.
        MOV.B     #100,MIN   ; MIN is an alias for R0.
        ~
--------------------------------------------------------------------------------
        ~
        .SECTION CD,CODE,ALIGN=4
                             ; .SECTION is an assembler directive that declares a section.
                             ; CD is the name of the current section.
        ~
```

1.3.2 Coding of Symbols

(1) Available Characters

The following ASCII characters can be used.

- Alphabetical uppercase and lowercase letters (A to Z, a to z)
- Numbers (0 to 9)
- Underscore (_)
- Dollar sign ($)

The assembler distinguishes uppercase letters from lowercase letters in symbols.

(2) First Character in a Symbol

The first character in a symbol must be one of the following.

- Alphabetical uppercase and lowercase letters (A to Z, a to z)
- Underscore (_)
- Dollar sign ($)

CAUTION!

The dollar sign character used alone is a reserved word that expresses the location counter.

Reference:

Reserved words → Programmer's Guide, 1.2, "Reserved Words"

(3) Maximum Length of a Symbol

A symbol may contain up to 251 characters.

The assembler ignores any characters after the first 251.

(4) Names that Cannot Be Used as Symbols

Reserved words cannot be used as symbols. The following names must not be used because they are used as internal symbols by the assembler.

_$$nnnnn (n is a number from 0 to 9.)

Note: Internal symbols are necessary for assembler internal processing. Internal symbols are not output to assemble listings or object modules.

1.4 Constants

1.4.1 Integer Constants

Integer constants are expressed with a prefix that indicates the radix.

The radix indicator prefix is a notation that indicates the radix of the constant.

- Binary numbers .... The radix indicator “B'” plus a binary constant.
- Octal numbers .... The radix indicator “Q'” plus an octal constant.
- Decimal numbers .... The radix indicator “D'” plus a decimal constant.
- Hexadecimal numbers .... The radix indicator “H'” plus a hexadecimal constant.

The assembler does not distinguish uppercase letters from lowercase letters in the radix indicator.

The radix indicator and the constant value must be written with no intervening space.

Examples:

```
        .DATA.B   B'10001000       ;
        .DATA.B   Q'210            ; These source statements express the same
        .DATA.B   D'136            ; numerical value.
        .DATA.B   H'88             ;
```

The radix indicator can be omitted. Integer constants with no radix indicator are normally decimal constants, although the radix for such constants can be changed with the .RADIX assembler directive.

Reference:

Interpretation of integer constants without a radix specified
→ Programmer's Guide, 5.2.8, "Other Assembler Directives", .RADIX

Supplement:

"Q" is used instead of "O" to avoid confusion with the digit 0.

1.4.2 Character Constants

Character constants are considered to be constants that represent ASCII codes.

Character constants are written by enclosing up to four ASCII characters in double quotation marks.

The following ASCII characters can be used in character constants.

ASCII code
- H'09 (tab)
- H'20 (space) to H'7E (tilde)

Examples:

```
        .DATA.L    "ABC"        ; This is the same as .DATA.L H'00414243.
        .DATA.W    "AB"         ; This is the same as .DATA.W H'4142.
        .DATA.B    "A"          ; This is the same as .DATA.B H'41.

                                    ; The ASCII code for A is: H'41
                                    ; The ASCII code for B is: H'42
                                    ; The ASCII code for C is: H'43
```

In addition, Japanese kana and kanji characters in shift JIS code or EUC code can be used. When using Japanese characters in shift JIS code or EUC code, be sure to specify the SJIS or EUC command line option, respectively. Note that the shift JIS code and EUC code cannot be used together in one source program.

Use two double quotation marks in succession to indicate a single double quotation mark in a character constant.

Example:

```
        .DATA.B    """"         ; This is a character constant consisting of a single
                                  double quotation mark.
        .DATA.L    "漢字"       ; Japanese kanji characters.
```

References:

SJIS command line option
→ User's Guide, 2.2.7, "Japanese Character Command Line Options," –SJIS

EUC command line option

→ User's Guide, 2.2.7, "Japanese Character Command Line Options," –EUC

1.4.3 Floating-Point Constants

Floating-point constants can be specified as operands in assembler directives for reserving floating-point constants.

Floating-Point Constant Representation:

Floating-point constants can be represented in decimal and hexadecimal.

- Decimal representation

$$\texttt{F'[\{}\pm\texttt{\}]}\left\{\begin{array}{l}\texttt{n[.[m]]}\\ \texttt{.m}\end{array}\right\}\texttt{[t[[\{}\pm\texttt{\}]xx]]}$$

F' .... Indicates that the number is decimal. It cannot be omitted.

$$\texttt{[\{}\pm\texttt{\}]}\left\{\begin{array}{l}\texttt{n[.[m]]}\\ \texttt{.m}\end{array}\right\}$$

"n" indicates the integer part in decimal. "m" indicates the fraction part in decimal. Either the integer part or the fraction part can be omitted. If the sign (±) is omitted, the assembler assumes it is positive.

t .... Indicates that the number is in either of the following precisions

- S: Single precision
- D: Double precision

If omitted, the assembler assumes the operation size of the assembler directive.

[{±}]xx .... Indicates the exponent part in decimal. If omitted, the assembler assumes 0. If the sign (±) is omitted, the assembler assumes it is positive.

Example:

F'0.5S-2	=	0.5×10^{-2}	=	0.005	=	H'3BA3D70A
F'.123D3	=	0.123×10^{3}	=	123	=	H'405EC00000000000

- Hexadecimal representation

  H'xxxx[.t]

  H'.......................... Indicates that the number is hexadecimal. It cannot be omitted.

  xxxx...................... Indicates the bit pattern of the floating-point constant in hexadecimal. If the bit pattern is shorter than the specified data length, it is aligned to the right end of the reserved area and 0s are added to the remaining bits in the reserved area. If the bit pattern is longer than the specified data length, the right-side bits of the bit pattern are allocated for the specified data length and the remaining bits of the bit pattern are ignored.

  t............................ Indicates that the number is in either of the following precisions
  - S: Single precision
  - D: Double precision

  If omitted, the assembler assumes the operation size of the assembler directive.

  This format directly specifies the bit pattern of the floating-point constant to represent data that is difficult to represent in decimal format, such as 0s for the specified data length or infinity.

  Example:

```
H'0123456789ABCDEF.S   = H'89ABCDEF
H'FFFF.D               = H'000000000000FFFF
```

Floating-Point Data Range:

Table 1-1 lists the floating-point data types.

Table 1-1 Floating-Point Data Types

Data Type	Description
Normalized number	The absolute value is between the underflow and overflow boundaries including the boundary values.
Denormalized number	The absolute value is between 0 and the underflow boundary.
Zero	The absolute value is 0.
Infinity	The absolute value is larger than the overflow boundary.
Not-a-Number (NAN)	A value that is not a numerical value. Includes sNAN (signaling NAN) and qNAN (quiet NAN).

These data types are shown on the following number line. NAN cannot be shown on the number line because it is not handled as a numerical value.

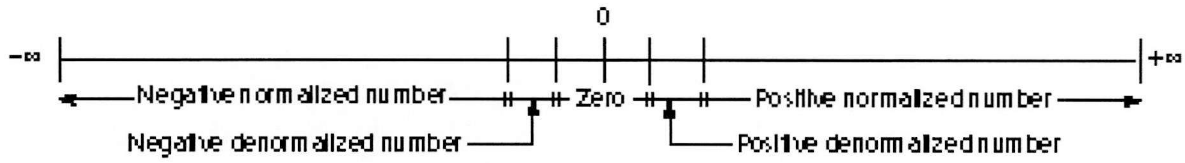


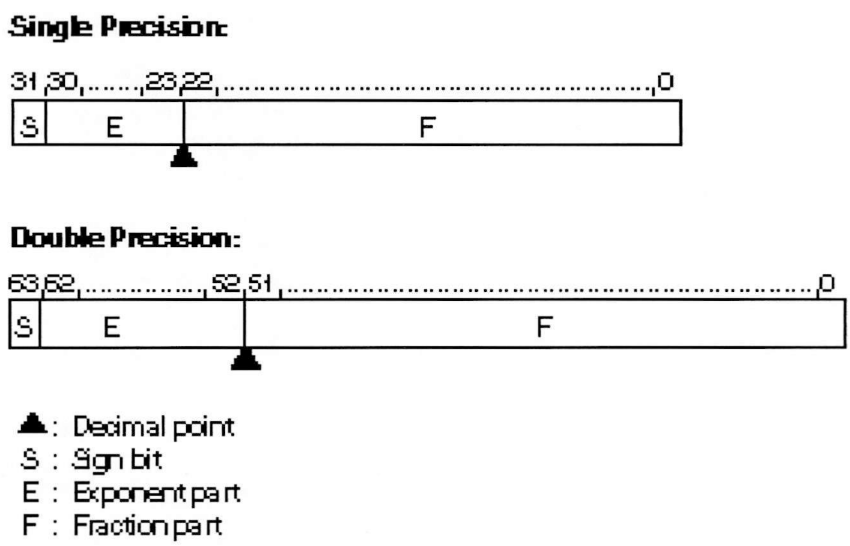
Table 1-2 lists the numerical value ranges the assembler can use.

Table 1-2 Data Types and Numerical Value Ranges (Absolute Value)

Data Type		Single Precision	Double Precision
Normalized number	Maximum value	3.40×10^{38}	1.79×10^{308}
	Minimum value	1.18×10^{-38}	2.23×10^{-308}
Denormalized number	Maximum value	1.17×10^{-38}	2.22×10^{-308}
	Minimum value	1.40×10^{-45}	4.94×10^{-324}

Floating-Point Data Format:

The floating-point data format is shown below:



• Sign bit (S)

Indicates the sign of a value. Positive and negative are represented by 0 and 1, respectively.

• Exponent part (E)

Indicates the exponent of a value. The actual exponent value is obtained by subtracting the bias value from the value specified in this exponent part.

• Fraction part (F)

Each bit has its own significance and corresponds to $2^{-1}, 2^{-2}, ..., 2^{-n}$ from the start bit, respectively ("n" is the bit length of the fraction part).

Table 1-3 shows the size of each parameter in data format.

Table 1-3 Data Format Size

Parameter	Single Precision	Double Precision
Bit length	32 bits	64 bits
Sign bit (S)	1 bit	1 bit
Exponent part (E)	8 bits	11 bits
Fraction part (F)	23 bits	52 bits
Bias of exponent value	127	1023

A floating-point number is represented using the symbols in table 1-3 as follows:

$$2^{E-bias} \cdot (-1)^S \cdot \begin{Bmatrix} (1.F) & : \text{Normalized number} \\ (0.F) & : \text{Denormalized number} \end{Bmatrix}$$

$$(1.F) = 1 + b0 \times 2^{-1} + b1 \times 2^{-2} + ... + b_{n-1} \times 2^{-n}$$
$$(0.F) = b0 \times 2^{-1} + b1 \times 2^{-2} + ... + b_{n-1} \times 2^{-n}$$

b: Bit location in the fraction part
n: Bit length of the fraction part

Table 1-4 shows the floating-point representation for each data type. NAN cannot be represented because it is not handled as a numerical value.

Table 1-4 Floating-Point Representation for Each Data Type

Data Type	Single Precision	Double Precision
Normalized number	$(-1)^S \cdot 2^{E-127} \cdot (1.\ F)$	$(-1)^S \cdot 2^{E-1023} \cdot (1.\ F)$
Denormalized number	$(-1)^S \cdot 2^{-126} \cdot (0.\ F)$	$(-1)^S \cdot 2^{-1022} \cdot (0.\ F)$
Zero	$(-1)^S \cdot 0$	$(-1)^S \cdot 0$
Infinity	$(-1)^S \cdot$	$(-1)^S \cdot$
Not-a-Number (NAN)	quiet NAN, signaling NAN	quiet NAN, signaling NAN

Valid Range for Floating-Point Constants:

When converting floating-point constants used in assembler directives for reserving floating-point numbers into object codes, the assembler rounds them in the following two modes to set the valid range.

- Round to Nearest even (RN)
  Rounds the least significant bit in the object code to its nearest absolute value. When two absolute values are at the same distance, rounds the least significant bit to become zero.
- Round to Zero (RZ)
  Rounds the least significant bit in the object code to zero.

  Example:

```
Object code of .FDATA.S F' 1S-1
        RN: H'3DCCCCCD
        RZ: H'3DCCCCCC
```

Reference:

Rounding mode setting
→ User's Guide, 2.2.10, "Floating-Point Data Command Line Options," –ROUND

Handling Denormalized Numbers:

The assembler handles denormalized numbers differently depending on the CPU type. In a CPU that does not handle denormalized numbers, if a value in the denormalized number range is used, warning number 841 occurs and the object code is output as zero.

In a CPU that handles denormalized numbers, if a value in the denormalized number range is used, warning number 842 occurs and the object code is output in denormalized numbers.

How to handle denormalized numbers can be switched with the DENORMALIZE command line option.

Examples:

```
CPU not handling denormalized numbers:
        .FDATA.S F' 1S-40    Warning 841, Object code H'00000000
CPU handling denormalized numbers:
        .FDATA.S F' 1S-40    Warning 842, Object code H'000116C2
```

Reference:

Denormalized numbers
→ User's Guide, 2.2.10, "Floating-Point Data Command Line Options," –DENORMALIZE

1.4.4 Fixed-Point Constants

Fixed-point constants can be specified as operands in the assembler directive for reserving fixed-point data.

Fixed-Point Number Representation:

Fixed-point numbers express real numbers ranging from –1.0 to 1.0 in decimal.

Word size and longword size are available for fixed-point numbers.

- Word-size fixed-point numbers

  Two-byte signed integers expressing real numbers ranging from –1.0 to 1.0.

  The real number expressed by 2-byte signed integer x (–32,768 < = x < = 32,767) is x/32768.

Example:

Fixed-point number	Word-size representation
-1.0	H'8000
-0.5	H'C000
0.0	H'0000
0.5	H'4000
1.0	H'7FFF

- Longword-size fixed-point numbers

  Four-byte signed integers expressing real numbers ranging from –1.0 to 1.0. The real number expressed by 4-byte signed integer x (–2,147,483,648 < = x < = 2,147,483,647) is x/2147483648.

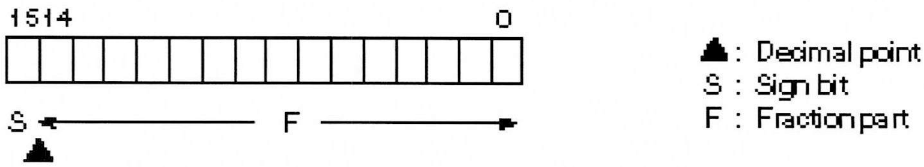
  Example:

Fixed-point number	Longword-size representation
-1.0	H'80000000
-0.5	H'C0000000
0.0	H'00000000
0.5	H'40000000
1.0	H'7FFFFFFF

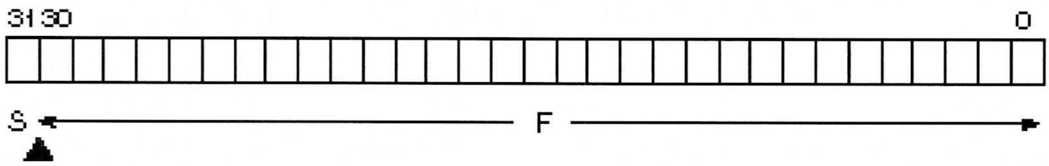
Fixed-Point Data Format:

The fixed-point data format consists of a sign bit and a 15-bit fraction part in word size, and a sign bit and a 31-bit fraction part in longword size. The decimal point is assumed to be fixed on the right of the sign bit.

- Word size



- Longword size



- Sign bit (S)

  Indicates the sign of a value. Positive and negative are represented by 0 and 1, respectively.

- Fraction part (F)

  Each bit has its own significance and corresponds to 2^{-1}, 2^{-2}, ..., 2^{-31} from the start bit, respectively.

Valid Range for Fixed-Point Numbers:

In long-word size, 31 bits can represent nine digits of data in decimal, but the assembler handles ten digits in decimal as a valid number, rounds the 35th bit in RN (round to the nearest absolute value) mode, and uses the high-order 31 bits of the result as fixed-point data.

Note: The actual fixed-point data range is –1.0 to 0.9999999999, but the assembler assumes 1.0 as 0.9999999999 and represents it as H'7FFFFFFF.

1.5 Location Counter

The location counter expresses the address (location) in memory where the corresponding object code (the result of converting executable instructions and data into code the microprocessor can regard) is stored.

The value of the location counter is automatically adjusted according to the object code output.

The value of the location counter can be changed intentionally using assembler directives.

Examples:

```
    ~

.ORG      H'00001000   ; This assembler directive sets the location counter to
                       ; H'00001000.

.DATA.W   H'FF         ; The object code generated by this assembler directive has
                       ; a length of 2 bytes.
                       ; The location counter changes to H'00001002.

.DATA.W   H'F0         ; The object code generated by this assembler directive has
                       ; a length of 2 bytes.
                       ; The location counter changes to H'00001004.

.DATA.W   H'10         ; The object code generated by this assembler directive has
                       ; a length of 2 bytes.
                       ; The location counter changes to H'00001006.

.ALIGN    4            ; The value of the location counter is corrected to be a multiple
                       ; of 4.
                       ; The location counter changes to H'00001008.

.DATA.L   H'FFFFFFFF   ; The object code generated by this assembler directive has
                       ; a length of 4 bytes.
                       ; The location counter changes to H'0000100C.

    ;         .ORG is an assembler directive that sets the value of the location counter.
    ;         .ALIGN is an assembler directive that adjusts the value of the location counter.
    ;         .DATA is an assembler directive that reserves data in memory.
    ;         .W is a specifier that indicates that data is handled in word (2 bytes) size.
    ;         .L is a specifier that indicates that data is handled in longword (4 bytes) size.

    ~
```

References:

Setting the value of the location counter

→ Programmer's Guide, 5.2.2, "Section and Location Counter Assembler Directives", .ORG

Correcting the value of the location counter

→ Programmer's Guide, 5.2.2, "Section and Location Counter Assembler Directives", .ALIGN

The location counter is referenced using the dollar sign symbol.

Examples:

```
LABEL1:   .EQU    $          ; This assembler directive sets the value of the
                             ; location counter to the symbol LABEL1.

;         .EQU is an assembler directive that sets the value to a symbol.
```

1.6 Expressions

Expressions are combinations of constants, symbols, and operators that derive a value, and are used as the operands of executable instructions and assembler directives.

1.6.1 Elements of Expression

An expression consists of terms, operators, and parentheses.

(1) Terms

The terms are the followings:

- A constant
- The location counter reference ($)
- A symbol (excluding aliases of the register name)
- The result of a calculation specified by a combination of the above terms and an operator.

An independent term is also a type of expression.

(2) Operators

Table 1-5 shows the operators supported by the assembler.

Table 1-5 Operators

Operator Type	Operator	Operation	Coding
Arithmetic operations	+	Unary plus	+ <term>
	–	Unary minus	– <term>
	+	Addition	<term1> + <term2>
	–	Subtraction	<term1> – <term2>
	*	Multiplication	<term1> * <term2>
	/	Division	<term1> / <term2>
Logic operations	~ ^	Unary negation	~ <term>
	&	Logical AND	<term1> & <term2>
	|	Logical OR	<term1> | <term2>
	~ ^	Exclusive OR	<term1> ~ <term2>
Shift operations	<<	Arithmetic left shift	<term 1> << <term 2>
	>>	Arithmetic right shift	<term 1> >> <term 2>

Table 1-5 Operators (cont)

Operator Type	Operator	Operation	Coding
Section set operations*	STARTOF	Derives the starting address of a section set.	STARTOF <section name>
	SIZEOF	Derives the size of a section set in bytes.	SIZEOF <section name>
Even/odd operations	$EVEN	1 when the value is a multiple of 2, and 0 otherwise	$EVEN <symbol>
	$ODD	0 when the value is a multiple of 2, and 1 otherwise	$ODD <symbol>
	$EVEN2	1 when the value is a multiple of 4, and 0 otherwise	$EVEN2 <symbol>
	$ODD2	0 when the value is a multiple of 4, and 1 otherwise	$ODD2 <symbol>
Extraction operations	HIGH	Extracts the high-order byte	HIGH <term>
	LOW	Extracts the low-order byte	LOW <term>
	HWORD	Extracts the high-order word	HWORD <term>
	LWORD	Extracts the low-order word	LWORD <term>

Note: See the supplement below.

Supplement:

In this assembly language, programs are divided into units called section. Sections are the units in which linkage processing is performed.

When there are multiple sections of the same type and same name within a given program, the linkage editor links them into a single "section set".

Reference:

Sections → Programmer's Guide, 2.1, "Sections"

(3) Parentheses

Parentheses modify the operation precedence.

See the next section, section 1.6.2, "Operation Precedence", for a description of the use of parentheses.

1.6.2 Operation Precedence

When multiple operations appear in a single expression, the order in which the processing is performed is determined by the operator precedence and by the use of parentheses. The assembler processes operations according to the following rules.

<Rule 1>
Processing starts from operations enclosed in parentheses.
When there are multiple parentheses, processing starts with the operations surrounded by the innermost parentheses.

<Rule 2>
Processing starts with the operator with the highest precedence.

<Rule 3>
Processing proceeds in the direction of the operator association rule when operators have the same precedence.

Table 1-6 shows the operator precedence and the association rule.

Table 1-6 Operator Precedence and Association Rules

<table>
<tr><th>Precedence</th><th>Operator</th><th>Association Rule</th></tr>
<tr><td>1 (high)</td><td>+ – ~ ^ STARTOF SIZEOF
$EVEN $ODD $EVEN2 $ODD2
HIGH LOW HWORD LWORD*</td><td>Operators are processed from right to left.</td></tr>
<tr><td>2</td><td>* /</td><td>Operators are processed from left to right.</td></tr>
<tr><td>3</td><td>+ –</td><td>Operators are processed from left to right.</td></tr>
<tr><td>4</td><td><< >></td><td>Operators are processed from left to right.</td></tr>
<tr><td>5</td><td>&</td><td>Operators are processed from left to right.</td></tr>
<tr><td>6 (low)</td><td>| ~ ^</td><td>Operators are processed from left to right.</td></tr>
</table>

Note: The operators of precedence 1 (highest precedence) are for unary operation.

The figures below show examples of expressions.

Example 1:

```
1 + ( 2 - ( 3 + ( 4 - 5 ) ) )
```

(a)

(b)

(c)

(d)

The assembler calculates this expression in the order (a) to (d).

The result of (a) is –1
The result of (b) is 2
The result of (c) is 0
The result of (d) is 1

The final result of this calculation is 1.

Example 2:

```
- H'FFFFFFF1 + H'000000F0 * H'00000010 | H'000000F0 & H'0000FFFF
```

(a) (b) (d)

(c)

(e)

The assembler calculates this expression in the order (a) to (e).

The result of (a) is H'0000000F
The result of (b) is H'00000F00
The result of (c) is H'00000F0F
The result of (d) is H'000000F0
The result of (e) is H'00000FFF

The final result of this calculation is H'00000FFF.

Example 3:

$$\underbrace{-\underbrace{\sim\underbrace{-\underbrace{\sim \mathtt{H'0000000F}}_{(a)}}_{(b)}}_{(c)}}_{(d)}$$

The assembler calculates this expression in the order (a) to (d).

The result of (a) is H'FFFFFFF0
The result of (b) is H'00000010
The result of (c) is H'FFFFFFEF
The result of (d) is H'00000011

The final result of this calculation is H'00000011.

1.6.3 Detailed Description on Operation

STARTOF Operation: Determines the start address of a section set after the specified sections are linked by the linkage editor.

SIZEOF Operation: Determines the size of a section set after the specified section are linked by the linkage editor.

Example:

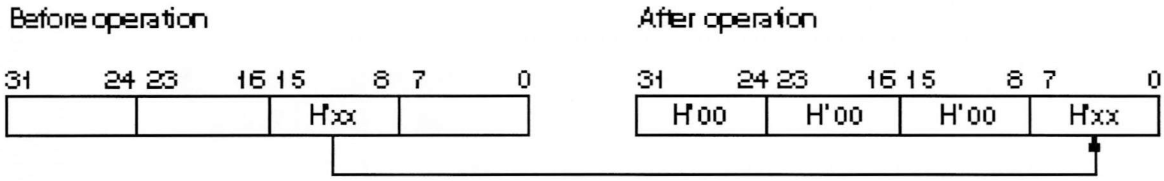
```
          .CPU        SH1
          .SECTION    INIT_RAM,DATA,ALIGN=4
          .RES.B      H'100
          .SECTION    INIT_DATA,DATA,ALIGN=4
INIT_BGN  .DATA.L     (STARTOF  INIT_RAM) .......................; (1)
INIT_END  .DATA.L     (STARTOF  INIT_RAM) + (SIZEOF INIT_RAM) ...; (2)
;
;
          .SECTION    MAIN,CODE,ALIGN=4
INITIAL:
          MOV.L       DATA1,R6
          MOV         #0,R5
          MOV.L       DATA1+4,R3
          BRA         LOOP2
          MOV.L       @R3,R4
LOOP1:
          MOV.L       R5,@R4
          ADD         #4,R4
LOOP2:
          MOV.L       @R6,R3
          CMP/HI      R3,R4
          BF          LOOP1
          RTS
          NOP
DATA1:
          .DATA.L     INIT_END
          .DATA.L     INIT_BGN
          .END
```

Initializes the data area in section INIT_RAM to 0.

(1) Determines the start address of section INIT_RAM.

(2) Determines the end address of section INIT_RAM.

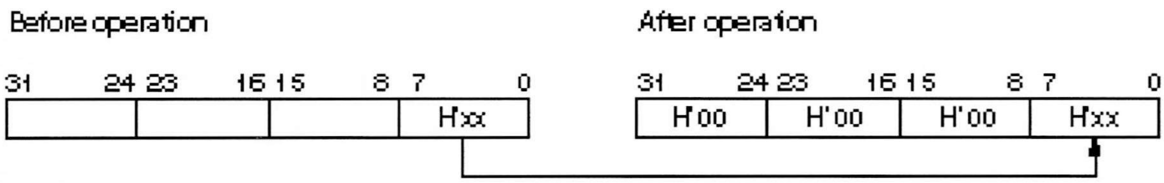
HIGH Operation: Extracts the high-order byte from the low-order two bytes of a 4-byte value.



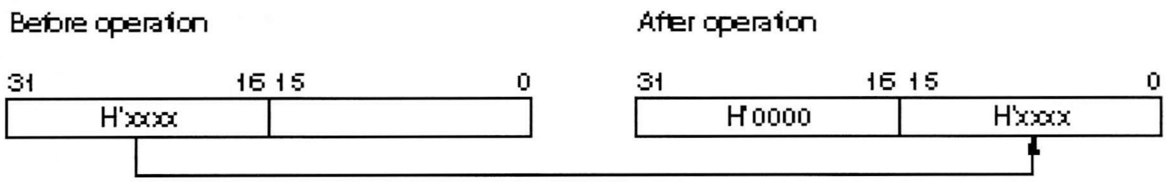
Example:

```
LABEL   .EQU    H'00007FFF
        .DATA   HIGH LABEL          ; Reserves integer data H'0000007F on memory.
```

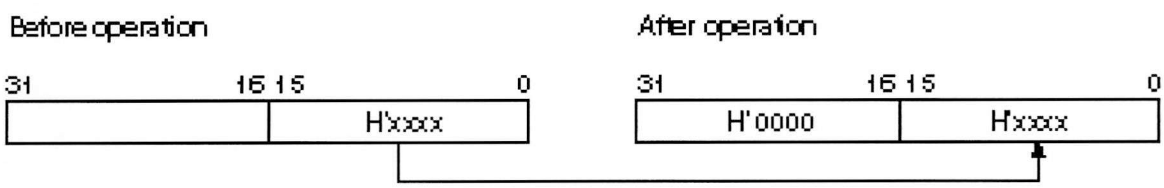
LOW Operation: Extracts the lowest-order one byte from a 4-byte value.



HWORD Operation: Extracts the high-order two bytes from a 4-byte value.



LWORD Operation: Extracts the low-order two bytes from a 4-byte value.



Even/Odd Operation: Determines if the value of the address symbol is a multiple of 2 or 4.

Table 1-7 shows the even/odd operations.

Table 1-7 Even/Odd Operations

Operator	Operation
$EVEN	1 when the value is a multiple of 2, and 0 otherwise
$ODD	0 when the value is a multiple of 2, and 1 otherwise
$EVEN2	1 when the value is a multiple of 4, and 0 otherwise
$ODD2	0 when the value is a multiple of 4, and 1 otherwise

Example:

To obtain the current program counter value using an $ODD2 operator.

```
LAB:
        MOVA    @(0,PC),R0
        ADD     #-4+2*$ODD2 LAB,R0          ; $ODD2 gives 0 when LAB is
                                            ; a multiple of 4, and gives 1 when
                                            ; LAB is not a multiple of 4.
```

1.6.4 Notes on Expressions

(1) Internal Processing

The assembler regards expression values as 32-bit signed values.

Example:

```
~H'F0
    The assembler regards H'F0 as H'000000F0.
    Therefore, the value of ~H'F0 is H'FFFFFF0F. (Note that this is not H'0000000F.)
```

(2) Arithmetic Operators

Where values must be determined at assembly, the multiplication and division operators cannot take terms that contain relative values (values which are not determined until the end of the linkage process) as their operands.

Example:

```
.IMPORT  SYM
.DATA    SYM/10           ; Correctly assembled.
.ORG     SYM/10           ; An error will occur.
```

Also, a divisor of 0 cannot be used with the division operator.

(3) Logic Operators

The logic operators cannot take terms that contain relative values as their operands.

Reference:

Relative values → Programmer's Guide, 2.2, "Absolute and Relative Values".

1.7 Character Strings

Character strings are sequences of character data.

The following ASCII characters can be used in character strings.

ASCII code { H'09 (tab)
H'20 (space) to H'7E (tilde)

A single character in a character string has as its value the ASCII code for that character and is represented as a byte sized data object. In addition, Japanese kana and kanji characters in shift JIS code or EUC code can be used. When using Japanese characters in shift JIS code or EUC code, be sure to specify the SJIS or EUC command line option, respectively. If not specified, Japanese characters are handled as the Japanese code specified by the host machine.

Character strings must be written enclosed in double quotation marks.

Use two double quotation marks in succession to indicate a single double quotation mark in a character string.

Examples:

```
          .SDATA   "Hello!"        ; This statement reserves the character string data
                                   ; Hello!
          .SDATA   "アセンブラ"     ; This statement reserves the character string data
                                   ; アセンブラ
          .SDATA   """Hello!"""    ; This statement reserves the character string data
                                   ; "Hello!"

;         .SDATA is an assembler directive that reserves character string data in memory.
```

Supplement:

The difference between character constants and character strings is as follows.

Character constants are numeric values. They have a data size of either 1 byte, 2 bytes, or 4 bytes.

Character strings cannot be handled as numeric values. A character string has a data size between 1 byte and 255 bytes.

References:

SJIS command line option

→ User's Guide, 2.2.7, "Japanese Character Command Line Options," –SJIS

EUC command line option

→ User's Guide, 2.2.7, "Japanese Character Command Line Options," –EUC

1.8 Local Label

1.8.1 Local Label Functions

A local label is valid locally between address symbols. Since a local label does not conflict with the other labels outside its scope, the user does not have to consider other label names. A local label can be defined by writing in the label field in the same way as a normal address symbol, and can be referenced by an operand.

An example of local label descriptions is shown below.

Example:

```
LABEL1:                         ; Local block 1 start
?0001:
          ~
          CMP/EQ    R1,R2
          BT        ?0002       ; Branches to ?0002 of local block 1
          BRA       ?0001       ; Branches to ?0001 of local block 1
?0002:
          ~
LABEL2:                         ; Local block 2 start
?0001:
          ~
          CMP/GE    R1,R2
          BT        ?0002       ; Branches to ?0002 of local block 2
          BRA       ?0001       ; Branches to ?0001 of local block 2
?0002:
LABEL3:                         ; Local block 3 start
```

Note:

A local label cannot be referenced during debugging.

A local label cannot be specified as any of the following items:

- Macro name
- Section name
- Object module name
- Label in .ASSIGNA, .ASSIGNC, .EQU, .ASSIGN, .REG, or .DEFINE
- Operand in .EXPORT, .IMPORT, or .GLOBAL

1.8.2 Description Method of Local Label

First Character:

A local label is a character string starting with a question mark (?).

Usable Characters:

The following ASCII characters can be used in a local label, except for the first character:

- Alphabetical uppercase and lowercase letters (A to Z and a to z)
- Numbers (0 to 9)
- Underscore (_)
- Dollar sign ($)

The assembler distinguishes uppercase letters from lowercase ones in local labels.

Maximum Length:

The length of local label characters is 2 to 16 characters. If 17 or more characters are specified, the assembler will not recognize them as a local label.

1.8.3 Scope of Local Labels

The scope of a local label is called a local block. Local blocks are separated by address symbols, or by the .SECTION directives.

The local label defined within a local block can be referenced in that local block.

A local label belonging to a local block is interpreted as being unique even if its spelling is the same as local labels in other local blocks; it does not cause an error.

Note:

The address symbols defined by the .EQU or .ASSIGN directive are not interpreted as delimiters for the local block.

Section 2 Basic Programming Knowledge

2.1 Sections

If source programs are compared to natural language writing, a section will correspond to a "chapter." The section is the processing unit used when the linkage editor links object modules.

2.1.1 Section Types by Usage

Sections are classified by usage into the following types.

- Code section
- Data section
- Common section
- Stack section
- Dummy section

(1) Code Section

The following can be written in a code section:

- Executable instructions
- Extended instructions
- Assembler directives that reserve initialized data.

Examples:

```
         .SECTION    CD,CODE,ALIGN=4     ; This assembler directive declares a
                                         ; code section with the name CD.

          MOV.L      X,R1                ; This is an executable instruction.
          MOV        R1,R2

           ~

         .ALIGN      4
X:       .DATA.L     H'FFFFFFFF          ; This assembler directive reserves
                                         ; initialized data.
           ~
```

(2) Data Section

The following can be written in a data section:

- Assembler directives that reserve initialized data.
- Assembler directives that reserve uninitialized data.

Examples:

```
        .SECTION     DT1,DATA,ALIGN=4      ; This assembler directive declares
                                           ; a data section with the name DT1.

        .DATA.W      H'FF00                ; These assembler directives reserve
        .DATA.B      H'FF                  ; initialized data.

                ~

        .SECTION     DT2,DATA,ALIGN=4      ; This assembler directive declares
                                           ; a data section with the name DT2.

        .RES.W       10                    ; These assembler directives reserve
        .RES.B       10                    ; data areas that do not have initial
                                           ; values.

                ~
```

(3) Common Section

A common section is used as a section to hold data that is shared between files when a source program consists of multiple source files.

The following can be written in a common section:

- Assembler directives that reserve initialized data.
- Assembler directives that reserve uninitialized data.

Supplement:

The linkage editor reserves common sections with the same name to the same area in memory. In the example shown in figure 2-1, the common section CM declared in file A and the common section CM declared in file B are reserved to the same area in memory.

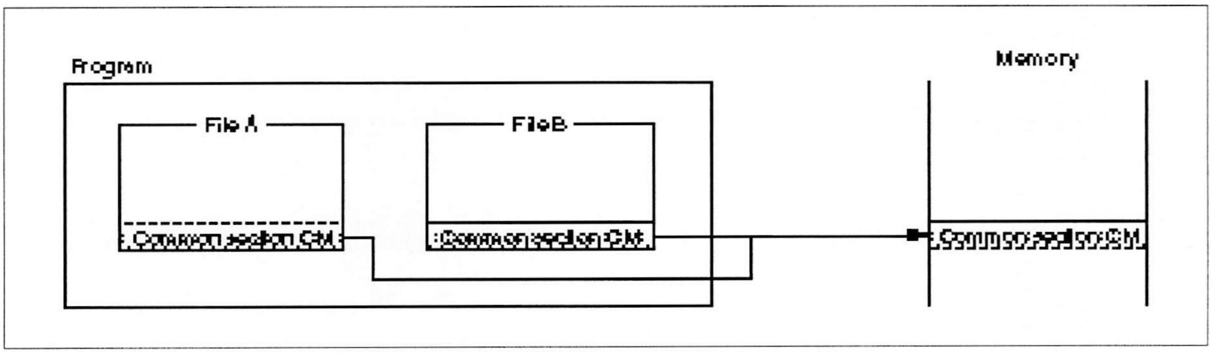


Figure 2-1 Memory Reservation of Common Section

(4) Stack Section

The section that the microprocessor uses as a stack area (an area for temporary data storage) is called the stack section.

The following can be written in the stack section:

- Assembler directives that reserve uninitialized data.

Examples:

```
         .SECTION ST,STACK,ALIGN=4     ; This assembler directive declares a
                                       ; stack section with the name ST.

         .RES.B   1024                 ; This assembler directive reserves a
                                       ; stack area of 1024 bytes.
STK:
```

(5) Dummy Section

A dummy section is a hypothetical section for representing data structures. The assembler does not output dummy sections to the object module.

The following can be written in a dummy section:

- Assembler directives that reserve uninitialized data.

Examples:

```
         .SECTION DM,DUMMY             ; This assembler directive declares
                                       ; a dummy section with the name DM.
         .RES.B  1                     ; The assembler does not output the
A:       .RES.B  1                     ; section DM to the object module.
B:       .RES.B  2
            ~
```

Specific methods for specifying data structures are described in the supplement on the next page.

Supplement:

As shown in figure 2-2, it is possible to access areas in memory by using address symbols from a dummy section.

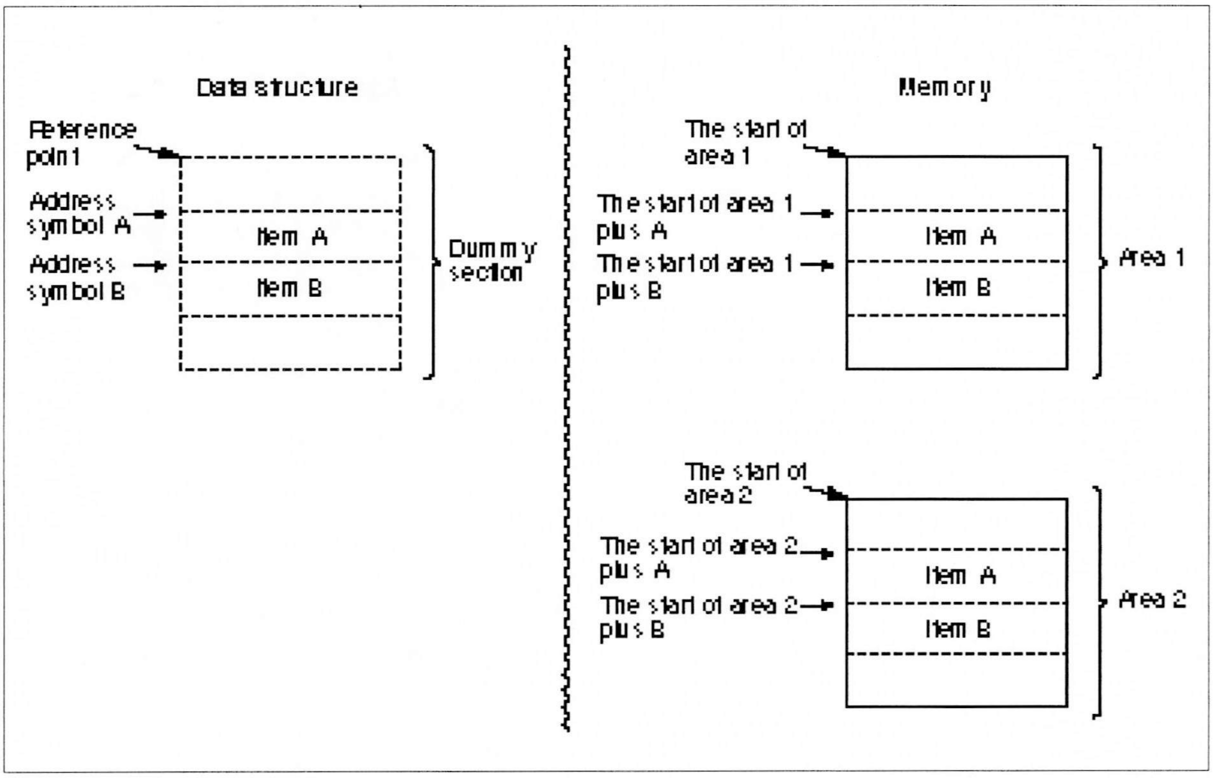


Figure 2-2 Data Structure Example Using Dummy Section

Example:

In the example above, assume that R1 holds the starting address of area 1 and R2 holds the starting address of area 2.

```
MOV.L   @(B,R1),R0     ; Moves the contents of item B in area 1 to R0.
MOV.L   R0,@(B,R2)     ; Moves the contents of R0 to item B in area 2.

   ~
```

CAUTION!

1. The following cannot be used in stack and dummy sections:

   a. Executable instructions
   b. Extended instructions
   c. Assembler directives that reserve initialized data (.DATA, .DATAB, .SDATA, .SDATAB, .SDATAC, .SDATAZ, .FDATA, .FDATAB, and .XDATA)

2. When using a data or common section, be sure to keep in mind whether that section is reserved to ROM or RAM.

2.1.2 Absolute Address Sections and Relative Address Sections

A section can be classified as either an absolute address section or as a relative address section depending on whether absolute start addresses are given to the sections at assembly.

(1) Absolute Address Section

The memory locations of absolute address sections are specified in the source program, and cannot be changed by the linkage editor. In this assembly language, locations in an absolute address section are expressed as absolute addresses, which are addresses that express the actual position in memory.

Examples:

```
.SECTION ABS,DATA,LOCATE=H'0000F000    ; ABS is an absolute address section.
                                       ; The starting address of section ABS is
                                       ; the absolute address H'0000F000.

.DATA.W   H'1111                       ; The constant H'1111 is reserved at
                                       ; the absolute address H'0000F000.

.DATA.W   H'2222                       ; The constant H'2222 is reserved at
                                       ; the absolute address H'0000F002.
```

(2) Relative Address Section

The locations in memory of relative section are not specified in the source program, but rather are determined when the sections are linked by the linkage editor. In this assembly language, locations in a relative address section are expressed as relative addresses, which are addresses that express the position relative to the start of the section itself.

Examples:

```
.SECTION   REL,DATA,ALIGN=4          ; REL is a relative address section.
                                     ; The starting address of section REL is
                                     ; determined after linkage.

.DATA.W    H'1111                    ; The constant H'1111 is reserved at the
                                     ; relative address H'00000000.

.DATA.W    H'2222                    ; The constant H'2222 is reserved at the
                                     ; relative address H'00000002.
```

Supplement:

Dummy sections correspond neither to relative nor to absolute address sections.

2.2 Absolute and Relative Values

Absolute values are determined when assembly completes. Relative values are not determined until the linkage editor completes.

2.2.1 Absolute Values

The following are the absolute values handled by the assembler.

(1) Constants

- Integer constants
- Character constants
- Symbols that have a value that is one of the above (hereafter referred to as constant symbols).

(2) Absolute Address Values

- The location counter referenced in an absolute address section
- The location counter referenced in a dummy section
- Symbols that have a value that is one of the above (hereafter referred to as absolute address symbols).

(3) Other Absolute Values

Expressions whose value is determined when assembly completes.

2.2.2 Relative Values

The following are the relative values handled by the assembler.

(1) Relative Address Values

- The location counter referenced in a relative address section
- Symbols that have the above as a value (hereafter referred to as relative address symbols).

(2) External Reference Values

Symbols that reference another file (hereafter referred to as import symbols).

(3) Other Relative Values

Expressions whose value is not determined until the linkage editor completes.

2.3 Symbol Definition and Reference

2.3.1 Symbol Definition

(1) Normal Definition

The normal method for defining a symbol is to write that symbol in the label field of a source statement. The value of that symbol will then be the value of the location counter at that point in the program.

Examples:

```
        .SECTION DT1,DATA,LOCATE=H'0000F000   ; This statement declares an
                                              ; absolute address section.
X1:     .DATA.W  H'1111                       ; The value of X1 becomes H'0000F000.
X2:     .DATA.W  H'2222                       ; The value of X2 becomes H'0000F002.

------------------------------------------------------------------------------

       .SECTION DT2,DATA,ALIGN=4              ; This statement declares a relative
                                              ; address section.
Y1:    .DATA.W  H'1111                        ; The value of Y1 is determined when
                                              ; linkage completes, and its value is
                                              ; the start address of the section.
Y2:    .DATA.W  H'2222                        ; The value of Y2 is determined when
                                              ; linkage completes, and its value is
                                              ; the start address of the section
                                              ; plus 2.
```

(2) Definition by Assembler Directive

Symbols can be defined by using assembler directives to set an arbitrary value or a special meaning.

Examples:

```
          .SECTION DT1,DATA,ALIGN=4   ; DT1 is the section name.
                                      ; A section name is also a type of symbol
                                      ; that expresses the start address of
                                      ; a section.
                                      ; However, the syntactic handling of address
                                      ; symbols and section names is different.

X:        .EQU     100                ; The value of X is 100.
                                      ; X cannot be redefined.

Y:        .ASSIGN  10                 ; The value of Y is 10.
                                      ; Y can be redefined.

Z:        .REG     R1                 ; Z becomes an alias of the general
                                      ; register R1.
                                      ; Z cannot be redefined.
```

2.3.2 Symbol Reference

There are three forms of symbol reference as follows:

- Forward reference
- Backward reference
- External reference

Supplement:

Figure 2-3 shows the meaning of the terms forward and backward as used in this manual.

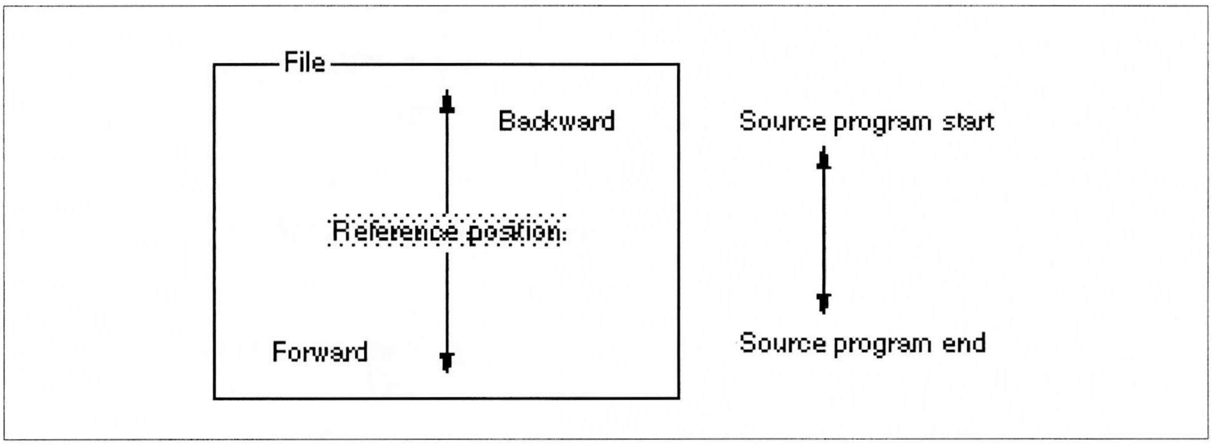


Figure 2-3 Meaning of the Terms Forward and Backward

Figure 2-4 shows the meaning of the term external as used in this manual.

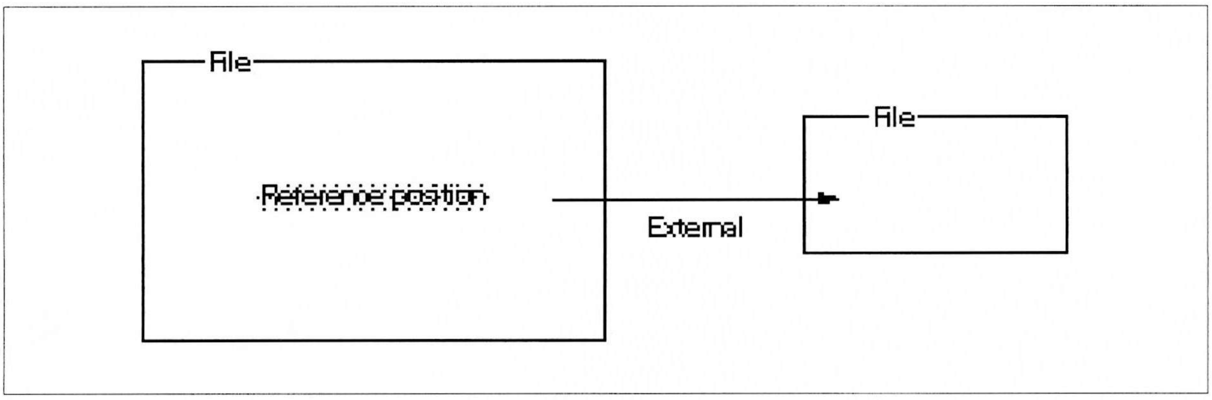


Figure 2-4 Meaning of the Term External

(1) Forward Reference

Forward reference means referencing a symbol that is defined forward from the point of reference.

Examples:

```
          ~
          BRA    FORWARD       ; BRA is a branch instruction.
                               ; This is a forward reference to the symbol FORWARD.
          ~
FORWARD:
          ~
```

(2) Backward Reference

Backward reference means referring to a symbol that is defined backward from the point of reference.

Examples:

```
          ~
BACK:
          ~

          BRA    BACK          ; BRA is a branch instruction.
                               ; This is a backward reference to the symbol BACK.
          ~
```

(3) External Reference

When a source program consists of multiple source files, a reference to a symbol defined in another file is called an external reference. External reference is described in the next section, 2.4, "Separate Assembly".

2.4 Separate Assembly

2.4.1 Separate Assembly

Separate assembly refers to the technique of creating a source program in multiple separate source files, and finally creating a single load module by linking together those source files' object modules using the linkage editor.

The process of developing software often consists of repeatedly correcting and reassembling the program. In such cases, if the source program is partitioned, it will be only necessary to reassemble the source file that was changed. As a result, the time required to construct the complete program will be significantly reduced.

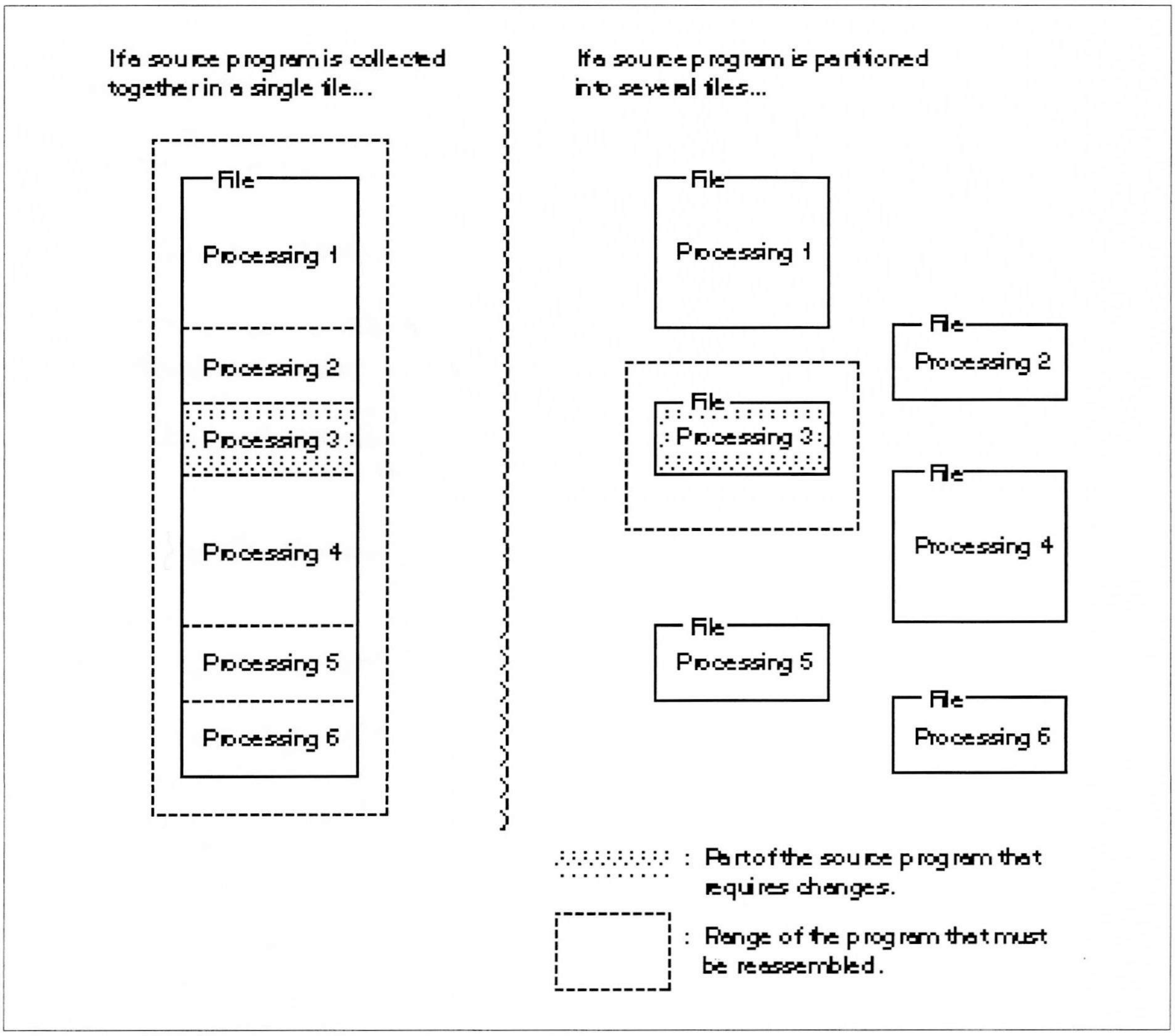


Figure 2-5 Relationship between the Changed Range of the Source Program and the Range of the Program that must be Reassembled

The procedure involved in separate assembly consists of steps 1 to 4.

1. Investigate methods for partitioning the program.

   Normally, programs are partitioned by function.

   Note that the memory reservation of the section must also be considered at this point.

2. Divide the source program into separate files and edit those files accordingly.

3. Assemble the individual files.

4. Link the individual object modules into a single load module.

2.4.2 Declaration of Export Symbols and Import Symbols

When a source program consists of multiple files, referencing a symbol defined in one file from another file is called "external reference" or "import." When referencing a symbol externally, it is necessary to declare to the assembler that "this symbol is shared between multiple files" (this declaration is called "external definition" or "export").

(1) Export Symbol Declaration

This declaration is used to declare that the definition of the symbol is valid in other files. .EXPORT or .GLOBAL directive is used to make this declaration.

(2) Import Symbol Declaration

This declaration is used to declare that a symbol defined in another file is referenced. .IMPORT or
.GLOBAL directive is used to make this declaration.

Examples:

In this example the symbol MAX is defined in file A and referenced in file B.

File A:

```
          ~
          .EXPORT   MAX       ; Declares MAX to be an export symbol.
MAX:      .EQU      100       ; Defines MAX.
          ~
```

File B:

```
          ~
          .IMPORT   MAX       ; Declares MAX to be an import symbol.
          MOV       #MAX,R0   ; References MAX.
          ~
```

Reference:

Symbol Export and Import

→ Programmer's Guide, 5.2.5, "Export and Import Assembler Directives", .EXPORT, .IMPORT, .GLOBAL

Section 3 Executable Instructions

3.1 Overview of Executable Instructions

The executable instructions are the instructions of microprocessor. The microprocessor interprets and executes the executable instructions in the object code stored in memory.

An executable instruction source statement has the following basic form.

```
[<symbol>:] Δ<mnemonic>[.<operation size>] [Δ<addressing mode>[,<addressing mode>]] [;<comment>]
 Label       Operation                      Operand                                  Comment
```

This section describes the mnemonic, operation size, and addressing mode. The other elements are described in detail in section 1, "Program Elements", in the Programmer's Guide.

(1) Mnemonic

The mnemonic expresses the executable instruction. Abbreviations that indicate the type of processing are provided as mnemonics for microprocessor instructions.

The assembler does not distinguish uppercase and lowercase letters in mnemonics.

(2) Operation Size

The operation size is the unit for processing data. The operation sizes vary with the executable instruction. The assembler does not distinguish uppercase and lowercase letters in the operation size.

Specifier	Data Size
B	Byte
W	Word (2 bytes)
L	Longword (4 bytes)
S	Single precision (4 bytes)
D	Double precision (8 bytes)

(3) Addressing Mode

The addressing mode specifies the data area accessed, and the destination address. The addressing modes vary with the executable instruction. Table 3-1 shows the addressing modes.

Table 3-1 Addressing Modes

Addressing Mode	Name	Description
Rn	Register direct	The contents of the specified register.
@Rn	Register indirect	A memory location. The value in Rn gives the start address of the memory accessed.
@Rn+	Register indirect with post-increment	A memory location. The value in Rn (before being incremented*1) gives the start address of the memory accessed. The microprocessor first uses the value in Rn for the memory reference, and increments Rn afterwards.
@–Rn	Register indirect with pre-decrement	A memory location. The value in Rn (after being decremented*2) gives the start address of the memory accessed. The microprocessor first decrements Rn, and then uses that value for the memory reference.
@(disp,Rn)	Register indirect with displacement*3	A memory location. The start address of the memory access is given by: the value of Rn plus the displacement (disp). The value of Rn is not changed.
@(R0,Rn)	Register indirect with index	A memory location. The start address of the memory access is given by: the value of R0 plus the value of Rn. The values of R0 and Rn are not changed.
@(disp,GBR)	GBR indirect with displacement	A memory location. The start address of the memory access is given by: the value of GBR plus the displacement (disp). The value of GBR is not changed.
@(R0,GBR)	GBR indirect with index	A memory location. The start address of the memory access is given by: the value of GBR plus the value of R0. The values of GBR and R0 are not changed.
@(disp,PC)	PC relative with displacement	A memory location. The start address of the memory access is given by: the value of the PC plus the displacement (disp).

Notes 1 to 3: See next page.

Table 3-1 Addressing Modes (cont)

Addressing Mode	Name	Description
symbol	PC relative specified with symbol	[When used as the operand of a branch instruction] The symbol directly indicates the destination address. The assembler derives a displacement (disp) from the symbol and the value of the PC, using the formula: disp = symbol – PC.
		[When used as the operand of a data move instruction] A memory location. The symbol indicates the start address of the memory accessed. The assembler derives a displacement (disp) from the symbol and the value of the PC, using the formula: disp = symbol – PC.
		[When used as the operand of an instruction that specifies the RS or RE register (LDRS or LDRE instruction)] A memory location. The symbol indicates the start address*4 of the memory accessed. The assembler derives a displacement (disp) from the symbol and the value of the PC, using the formula: disp = symbol – PC.
#imm	Immediate	Indicates a constant.

Notes: 1. Increment

The amount of the increment is 1 when the operation size is a byte, 2 when the operation size is a word (two bytes), and 4 when the operation size is a longword (four bytes).

2. Decrement

The amount of the decrement is 1 when the operation size is a byte, 2 when the operation size is a word, and 4 when the operation size is a longword.

3. Displacement

A displacement is the distance between two points. In this assembly language, the unit of displacement values is in bytes.

4. Start address

Refer to Programmer's Guide, 10.1, "Overview of Automatic Repeat Loop Generation Function."

The values that can be used for the displacement vary with the addressing mode and the operation size.

Table 3-2 Allowed Displacement Values

Addressing Mode	Displacement*
@(disp,Rn)	When the operation size is byte (B): H'00000000 to H'0000000F (0 to 15)
	When the operation size is word (W): H'00000000 to H'0000001E (0 to 30)
	When the operation size is longword (L): H'00000000 to H'0000003C (0 to 60)
@(disp,GBR)	When the operation size is byte (B): H'00000000 to H'000000FF (0 to 255)
	When the operation size is word (W): H'00000000 to H'000001FE (0 to 510)
	When the operation size is longword (L): H'00000000 to H'000003FC (0 to 1020)
@(disp,PC)	[When used as an operand of a move instruction]
	When the operation size is word (W): H'00000000 to H'000001FE (0 to 510)
	When the operation size is longword (L): H'00000000 to H'000003FC (0 to 1020)
	[When used as an operand of an instruction that sets the RS or RE register (LDRS or LDRE)]
	H'FFFFFF00 to H'000000FE (–256 to 254)

Note: Units are bytes, and numbers in parentheses are decimal.

Table 3-2 Allowed Displacement Values (cont)

Addressing Mode	Displacement*
symbol	[When used as a branch instruction operand] When used as an operand for a conditional branch instruction (BT, BF, BF/S, or BT/S): H'00000000 to H'000000FF (0 to 255) H'FFFFFF00 to H'FFFFFFFF (–256 to –1) When used as an operand for an unconditional branch instruction (BRA or BSR) H'00000000 to H'00000FFF (0 to 4095) H'FFFFF000 to H'FFFFFFFF (–4096 to –1) [When used as the operand of a data move instruction] When the operation size is word (W): H'00000000 to H'000001FE (0 to 510) When the operation size is longword (L): H'00000000 to H'000003FC (0 to 1020) [When used as an operand of an instruction that sets the RS or RE register (LDRS or LDRE)] H'FFFFFF00 to H'000000FE (–256 to 254)

Note: Units are bytes, and numbers in parentheses are decimal.

The values that can be used for immediate values vary with the executable instruction.

Table 3-3 Allowed Immediate Values

Executable Instruction	Immediate Value	
TST, AND, OR, XOR	H'00000000 to H'000000FF	(0 to 255)
MOV	H'00000000 to H'000000FF H'FFFFFF80 to H'FFFFFFFF	(0 to 255) (–128 to –1)*1
ADD, CMP/EQ	H'00000000 to H'000000FF H'FFFFFF80 to H'FFFFFFFF	(0 to 255) (–128 to –1)*1
TRAPA	H'00000000 to H'000000FF	(0 to 255)
SETRC	H'00000001 to H'000000FF	(1 to 255)*2

Notes: 1. Values in the range H'FFFFFF80 to H'FFFFFFFF can be written as positive decimal values.

2. When zero is set as the immediate values of the SETRC instruction, warning number 835 occurs and the object code is output as zero. In this case, the range to be repeated is executed once.
When an import symbol is set as the immediate values of the SETRC instruction, the linkage editor checks the range from H'00000000 to H'000000FF (0 to 255).

CAUTION!

The assembler corrects the value of displacements under certain conditions.

Condition		Type of Correction
When the operation size is a word and the displacement is not a multiple of 2	→	The lowest bit of the displacement is discarded, resulting in the value being a multiple of 2.
When the operation size is a longword and the displacement is not a multiple of 4	→	The lower 2 bits of the displacement are discarded, resulting in the value being a multiple of 4.
When the displacement of the branch instruction is not a multiple of 2	→	The lowest bit of the displacement is discarded, resulting in the value being a multiple of 2.

Be sure to take this correction into consideration when using operands of the mode @(disp,Rn), @(disp,GBR), and @(disp,PC).

Example: `MOV.L @(63,PC),R0`

The assembler corrects the 63 to be 60, and generates object code identical to that for the statement MOV.L @(60,PC),R0, and warning number 870 occurs.

3.2 Notes on Executable Instructions

3.2.1 Notes on the Operation Size

The operation size that can be specified vary with the mnemonic and the addressing mode combination.

SH-1 Executable Instruction and Operation Size Combinations:

Table 3-4 shows the SH-1 allowable executable instruction and operation size combinations.

Table 3-4 SH-1 Executable Instruction and Operation Size Combinations (Part 1)

1. Data Move Instructions		**Operation Sizes**				
Mnemonic	**Addressing Mode**	**B**	**W**	**L**	**Default when Omitted**	
MOV	#imm,Rn	O			B	*1
MOV	@(disp,PC),Rn	×	O	O	L	
MOV	symbol,Rn	×	O	O	L	
MOV	Rn,Rm	×	×	O	L	
MOV	Rn,@Rm	O	O	O	L	
MOV	@Rn,Rm	O	O	O	L	
MOV	Rn,@–Rm	O	O	O	L	
MOV	@Rn+,Rm	O	O	O	L	
MOV	R0,@(disp,Rn)	O	O	O	L	
MOV	Rn,@(disp,Rm)	×	×	O	L	*2
MOV	@(disp,Rn),R0	O	O	O	L	
MOV	@(disp,Rn),Rm	×	×	O	L	*3
MOV	Rn,@(R0,Rm)	O	O	O	L	
MOV	@(R0,Rn),Rm	O	O	O	L	
MOV	R0,@(disp,GBR)	O	O	O	L	
MOV	@(disp,GBR),R0	O	O	O	L	
MOVA	#imm,R0	×	×		L	
MOVA	@(disp,PC),R0	×	×	O	L	
MOVA	symbol,R0	×	×	O	L	

Notes 1 to 3: See next page.

Table 3-4 SH-1 Executable Instruction and Operation Size Combinations (Part 1) (cont)

1. Data Move Instructions **Operation Sizes**

Mnemonic	Addressing Mode	B	W	L	Default when Omitted
MOVT	Rn	×	×	O	L
SWAP	Rn,Rm	O	O	×	W
XTRCT	Rn,Rm	×	×	O	L

Symbol meanings:

Rn, Rm	A general register (R0 to R15)
R0	General register R0 (when only R0 can be specified)
SR	Status register
GBR	Global base register
VBR	Vector base register
MACH, MACL	Multiplication and accumulation register
PR	Procedure register
PC	Program counter
imm	An immediate value
disp	A displacement value
symbol	A symbol
B	Byte
W	Word (2 bytes)
L	Longword (4 bytes)
O	Valid specification
×	Invalid specification: The assembler regards instructions with this combination as the specification being omitted.
....	The assembler regards them as extended instructions.

Notes: 1. In size selection mode, the assembler selects the operation size according to the imm value.

2. In this case, Rn must be one of R1 to R15.

3. In this case, Rm must be one of R1 to R15.

References:

Extended instructions

→ Programmer's Guide, 9.2, "Extended Instructions Related to Automatic Literal Pool Generation"

Size selection mode

→ Programmer's Guide, 9.3, "Size Mode for Automatic Literal Pool Generation"

Table 3-4 SH-1 Executable Instruction and Operation Size Combinations (Part 2)

2. Arithmetic Operation Instructions		Operation Sizes			
Mnemonic	Addressing Mode	B	W	L	Default when Omitted
ADD	Rn,Rm	×	×	O	L
ADD	#imm,Rn	×	×	O	L
ADDC	Rn,Rm	×	×	O	L
ADDV	Rn,Rm	×	×	O	L
CMP/EQ	#imm,R0	×	×	O	L
CMP/EQ	Rn,Rm	×	×	O	L
CMP/HS	Rn,Rm	×	×	O	L
CMP/GE	Rn,Rm	×	×	O	L
CMP/HI	Rn,Rm	×	×	O	L
CMP/GT	Rn,Rm	×	×	O	L
CMP/PZ	Rn	×	×	O	L
CMP/PL	Rn	×	×	O	L
CMP/STR	Rn,Rm	×	×	O	L
DIV1	Rn,Rm	×	×	O	L
DIV0S	Rn,Rm	×	×	O	L
DIV0U	(no operands)	×	×	×	—
EXTS	Rn,Rm	O	O	×	W
EXTU	Rn,Rm	O	O	×	W
MAC	@Rn+,@Rm+	×	O	×	W
MULS	Rn,Rm	×	O	O	L *
MULU	Rn,Rm	×	O	O	L *
NEG	Rn,Rm	×	×	O	L
NEGC	Rn,Rm	×	×	O	L
SUB	Rn,Rm	×	×	O	L
SUBC	Rn,Rm	×	×	O	L
SUBV	Rn,Rm	×	×	O	L

Note: The object code generated when W is specified is the same as that generated when L is specified.

Table 3-4 SH-1 Executable Instruction and Operation Size Combinations (Part 3)

3. Logic Operation Instructions		Operation Sizes			
Mnemonic	**Addressing Mode**	**B**	**W**	**L**	**Default when Omitted**
AND	Rn,Rm	×	×	O	L
AND	#imm,R0	×	×	O	L
AND	#imm,@(R0,GBR)	O	×	×	B
NOT	Rn,Rm	×	×	O	L
OR	Rn,Rm	×	×	O	L
OR	#imm,R0	×	×	O	L
OR	#imm,@(R0,GBR)	O	×	×	B
TAS	@Rn	O	×	×	B
TST	Rn,Rm	×	×	O	L
TST	#imm,R0	×	×	O	L
TST	#imm,@(R0,GBR)	O	×	×	B
XOR	Rn,Rm	×	×	O	L
XOR	#imm,R0	×	×	O	L
XOR	#imm,@(R0,GBR)	O	×	×	B

Table 3-4 SH-1 Executable Instruction and Operation Size Combinations (Part 4)

4. Shift Instructions		Operation Sizes			
Mnemonic	**Addressing Mode**	**B**	**W**	**L**	**Default when Omitted**
ROTL	Rn	×	×	O	L
ROTR	Rn	×	×	O	L
ROTCL	Rn	×	×	O	L
ROTCR	Rn	×	×	O	L
SHAL	Rn	×	×	O	L
SHAR	Rn	×	×	O	L
SHLL	Rn	×	×	O	L
SHLR	Rn	×	×	O	L
SHLL2	Rn	×	×	O	L
SHLR2	Rn	×	×	O	L
SHLL8	Rn	×	×	O	L
SHLR8	Rn	×	×	O	L
SHLL16	Rn	×	×	O	L
SHLR16	Rn	×	×	O	L

Table 3-4 SH-1 Executable Instruction and Operation Size Combinations (Part 5)

5. Branch Instructions		Operation Sizes			
Mnemonic	**Addressing Mode**	**B**	**W**	**L**	**Default when Omitted**
BF	symbol	×	×	×	—
BT	symbol	×	×	×	—
BRA	symbol	×	×	×	—
BSR	symbol	×	×	×	—
JMP	@Rn	×	×	×	—
JSR	@Rn	×	×	×	—
RTS	(no operands)	×	×	×	—

Table 3-4 SH-1 Executable Instruction and Operation Size Combinations (Part 6)

6. System Control Instructions			Operation Sizes			
Mnemonic	**Addressing Mode**		**B**	**W**	**L**	**Default when Omitted**
CLRT		(no operands)	×	×	×	—
CLRMAC		(no operands)	×	×	×	—
LDC	Rn,SR		×	×	O	L
LDC	Rn,GBR		×	×	O	L
LDC	Rn,VBR		×	×	O	L
LDC	@Rn+,SR		×	×	O	L
LDC	@Rn+,GBR		×	×	O	L
LDC	@Rn+,VBR		×	×	O	L
LDS	Rn,MACH		×	×	O	L
LDS	Rn,MACL		×	×	O	L
LDS	Rn,PR		×	×	O	L
LDS	@Rn+,MACH		×	×	O	L
LDS	@Rn+,MACL		×	×	O	L
LDS	@Rn+,PR		×	×	O	L
NOP		(no operands)	×	×	×	—
RTE		(no operands)	×	×	×	—
SETT		(no operands)	×	×	×	—
SLEEP		(no operands)	×	×	×	—
STC	SR,Rn		×	×	O	L
STC	GBR,Rn		×	×	O	L
STC	VBR,Rn		×	×	O	L
STC	SR,@–Rn		×	×	O	L
STC	GBR,@–Rn		×	×	O	L
STC	VBR,@–Rn		×	×	O	L
STS	MACH,Rn		×	×	O	L
STS	MACL,Rn		×	×	O	L
STS	PR,Rn		×	×	O	L
STS	MACH,@–Rn		×	×	O	L
STS	MACL,@–Rn		×	×	O	L
STS	PR,@–Rn		×	×	O	L
TRAPA	#imm		×	×	O	L

SH-2 Executable Instruction and Operation Size Combinations:

Table 3-5 shows the executable instruction and operation size combinations for the SH-2 instructions added to those of the SH-1.

Table 3-5 SH-2 Executable Instruction and Operation Size Combinations (Part 1)

1. Arithmetic Operation Instructions **Operation Sizes**

Mnemonic	Addressing Mode	B	W	L	Default when Omitted
MAC	@Rn+,@Rm+	×	O	O	W
MUL	Rn,Rm	×	×	O	L
DMULS	Rn,Rm	×	×	O	L
DMULU	Rn,Rm	×	×	O	L
DT	Rn	×	×	×	—

Table 3-5 SH-2 Executable Instruction and Operation Size Combinations (Part 2)

2. Branch Instructions **Operation Sizes**

Mnemonic	Addressing Mode	B	W	L	Default when Omitted
BF/S	symbol	×	×	×	—
BT/S	symbol	×	×	×	—
BRAF	Rn	×	×	×	—
BSRF	Rn	×	×	×	—

SH-2E Executable Instruction and Operation Size Combinations:

Table 3-6 shows the executable instruction and operation size combinations for the SH-2E instructions added to those of the SH-2.

Table 3-6 SH-2E Executable Instruction and Operation Size Combinations (Part 1)

1. Data Move Instructions — **Operation Sizes**

Mnemonic	Addressing Mode	B	W	L	S	Default when Omitted
FLDI0	FRn	×	×	×	O	S
FLDI1	FRn	×	×	×	O	S
FMOV	@Rm,FRn	×	×	×	O	S
FMOV	FRn,@Rm	×	×	×	O	S
FMOV	@Rm+,FRn	×	×	×	O	S
FMOV	FRn,@-Rm	×	×	×	O	S
FMOV	@(R0,Rm),FRn	×	×	×	O	S
FMOV	FRm,@(R0,Rm)	×	×	×	O	S
FMOV	FRm,FRn	×	×	×	O	S

Symbol meanings:

FRm,FRn .... Floating-point register
FR0 .... FR0 floating-point register (when only FR0 can be specified)
FPUL .... FPU low register
FPSCR .... FPU status control register
S.................................. Single precision (4 bytes)

Table 3-6 SH-2E Executable Instruction and Operation Size Combinations (Part 2)

2. Arithmetic Operation Instructions		Operation Sizes				
Mnemonic	**Addressing Mode**	**B**	**W**	**L**	**S**	**Default when Omitted**
FABS	FRn	×	×	×	O	S
FADD	FRm,FRn	×	×	×	O	S
FCMP/EQ	FRm,FRn	×	×	×	O	S
FCMP/GT	FRm,FRn	×	×	×	O	S
FDIV	FRm,FRn	×	×	×	O	S
FMAC	FR0,FRm,FRn	×	×	×	O	S
FMUL	FRm,FRn	×	×	×	O	S
FNEG	FRn	×	×	×	O	S
FSUB	FRm,FRn	×	×	×	O	S

Table 3-6 SH-2E Executable Instruction and Operation Size Combinations (Part 3)

3. System Control Instructions		Operation Sizes				
Mnemonic	**Addressing Mode**	**B**	**W**	**L**	**S**	**Default when Omitted**
FLDS	FRm,FPUL	×	×	×	O	S
FLOAT	FPUL,FRn	×	×	×	O	S
FSTS	FPUL,FRn	×	×	×	O	S
FTRC	FRm,FPUL	×	×	×	O	S
LDS	Rm,FPUL	×	×	O	×	L
LDS	@Rm+,FPUL	×	×	O	×	L
LDS	Rm,FPSCR	×	×	O	×	L
LDS	@Rm+,FPSCR	×	×	O	×	L
STS	FPUL,Rn	×	×	O	×	L
STS	FPUL,@-Rn	×	×	O	×	L
STS	FPSCR,Rn	×	×	O	×	L
STS	FPSCR,@-Rn	×	×	O	×	L

SH-3 Executable Instruction and Operation Size Combinations:

Table 3-7 shows the executable instruction and operation size combinations for the SH-3 instructions added to those of the SH-2.

Table 3-7 SH-3 Executable Instruction and Operation Size Combinations (Part 1)

1. Data Move Instructions — **Operation Sizes**

Mnemonic	Addressing Mode	B	W	L	Default when Omitted
PREF	@Rn	×	×	×	—

Symbol meanings:

Rn_BANK .... Bank general register
SSR.............................. Save status register
SPC.............................. Save program counter

Table 3-7 SH-3 Executable Instruction and Operation Size Combinations (Part 2)

2. Shift Instructions — **Operation Sizes**

Mnemonic	Addressing Mode	B	W	L	Default when Omitted
SHAD	Rn,Rm	×	×	O	L
SHLD	Rn,Rm	×	×	O	L

Table 3-7 SH-3 Executable Instruction and Operation Size Combinations (Part 3)

3. System Control Instructions — **Operation Sizes**

Mnemonic	Addressing Mode	B	W	L	Default when Omitted
CLRS	(no operands)	×	×	×	—
SETS	(no operands)	×	×	×	—
LDC	Rm,SSR	×	×	O	L
LDC	Rm,SPC	×	×	O	L
LDC	Rm,Rn_BANK	×	×	O	L
LDC	@Rm+,SSR	×	×	O	L
LDC	@Rm+,SPC	×	×	O	L
LDC	@Rm+,Rn_BANK	×	×	O	L
STC	SSR,Rn	×	×	O	L
STC	SPC,Rn	×	×	O	L
STC	Rm_BANK,Rn	×	×	O	L
STC	SSR,@–Rn	×	×	O	L
STC	SPC,@–Rn	×	×	O	L
STC	Rm_BANK,@–Rn	×	×	O	L
LDTLB	(no operands)	×	×	×	—

SH-3E Executable Instruction and Operation Size Combinations:

Table 3-8 shows the executable instruction and operation size combinations for the SH-3E instructions added to those of the SH-3.

Table 3-8 SH-3E Executable Instruction and Operation Size Combinations (Part 1)

1. Data Move Instructions — **Operation Sizes**

Mnemonic	Addressing Mode	B	W	L	S	Default when Omitted
FLDI0	FRn	×	×	×	O	S
FLDI1	FRn	×	×	×	O	S
FMOV	@Rm,FRn	×	×	×	O	S
FMOV	FRm,@Rn	×	×	×	O	S
FMOV	@Rm+,FRn	×	×	×	O	S
FMOV	FRm,@–Rn	×	×	×	O	S
FMOV	@(R0,Rm),FRn	×	×	×	O	S
FMOV	FRn,@(R0,Rn)	×	×	×	O	S
FMOV	FRm,FRn	×	×	×	O	S

Symbol meanings:

FRm,FRn .... Floating-point register
FR0 .... FR0 floating-point register (when only FR0 can be specified)
FPUL .... FPU low register
FPSCR .... FPU status control register
S.................................. Single precision (4 bytes)

Table 3-8 SH-3E Executable Instruction and Operation Size Combinations (Part 2)

2. Arithmetic Operation Instructions — **Operation Sizes**

Mnemonic	Addressing Mode	B	W	L	S	Default when Omitted
FABS	FRn	×	×	×	O	S
FADD	FRm,FRn	×	×	×	O	S
FCMP/EQ	FRm,FRn	×	×	×	O	S
FCMP/GT	FRm,FRn	×	×	×	O	S
FDIV	FRm,FRn	×	×	×	O	S
FMAC	FR0,FRm,FRn	×	×	×	O	S
FMUL	FRm,FRn	×	×	×	O	S
FNEG	FRn	×	×	×	O	S
FSQRT	FRn	×	×	×	O	S
FSUB	FRm,FRn	×	×	×	O	S

Table 3-8 SH-3E Executable Instruction and Operation Size Combinations (Part 3)

3. System Control Instructions — **Operation Sizes**

Mnemonic	Addressing Mode	B	W	L	S	Default when Omitted
FLDS	FRm,FPUL	×	×	×	O	S
FLOAT	FPUL,FRn	×	×	×	O	S
FSTS	FPUL,FRn	×	×	×	O	S
FTRC	FRm,FPUL	×	×	×	O	S
LDS	Rm,FPUL	×	×	O	×	L
LDS	@Rm+,FPUL	×	×	O	×	L
LDS	Rm,FPSCR	×	×	O	×	L
LDS	@Rm+,FPSCR	×	×	O	×	L
STS	FPUL,Rn	×	×	O	×	L
STS	FPUL,@–Rn	×	×	O	×	L
STS	FPSCR,Rn	×	×	O	×	L
STS	FPSCR,@–Rn	×	×	O	×	L

SH-4 Executable Instruction and Operation Size Combinations:

Table 3-9 shows the executable instruction and operation size combinations for the SH-4 instructions added to those of the SH-3E.

Table 3-9 SH-4 Executable Instruction and Operation Size Combinations (Part 1)

1. Data Move Instructions **Operation Sizes**

Mnemonic	Addressing Mode	B	W	L	S	D	Default when Omitted
FMOV	DRm,DRn	×	×	×	×	O	D
FMOV	DRm,@Rn	×	×	×	×	O	D
FMOV	DRm,@-Rn	×	×	×	×	O	D
FMOV	DRm,@(R0,Rn)	×	×	×	×	O	D
FMOV	@Rm,DRn	×	×	×	×	O	D
FMOV	@Rm+,DRn	×	×	×	×	O	D
FMOV	@(R0,Rm),DRn	×	×	×	×	O	D
FMOV	DRm,XDn	×	×	×	×	O	D
FMOV	XDm,DRn	×	×	×	×	O	D
FMOV	XDm,XDn	×	×	×	×	O	D
FMOV	XDm,@Rn	×	×	×	×	O	D
FMOV	XDm,@-Rn	×	×	×	×	O	D
FMOV	XDm,@(R0,Rn)	×	×	×	×	O	D
FMOV	@Rm,XDn	×	×	×	×	O	D
FMOV	@Rm+,XDn	×	×	×	×	O	D
FMOV	@(R0,Rm),XDn	×	×	×	×	O	D

Symbol meanings:

DRm,DRn .... Double-precision floating-point register
XDm,XDn...................... Extended double-precision floating-point register
FVm,FVn .... Single-precision floating-point vector register
XMTRX......................... Single-precision floating-point extended register matrix
DBR.............................. Debug vector base register
SGR .... Save general register 15
D .... Double precision (8 bytes)

Table 3-9 SH-4 Executable Instruction and Operation Size Combinations (Part 2)

2. Arithmetic Operation Instructions Operation Sizes

Mnemonic	Addressing Mode	B	W	L	S	D	Default when Omitted
FABS	DRn	×	×	×	×	O	D
FADD	DRm,DRn	×	×	×	×	O	D
FCMP/EQ	DRm,DRn	×	×	×	×	O	D
FCMP/GT	DRm,DRn	×	×	×	×	O	D
FDIV	DRm,DRn	×	×	×	×	O	D
FIPR	FVm,FVn	×	×	×	O	×	S
FMUL	DRm,DRn	×	×	×	×	O	D
FNEG	DRn	×	×	×	×	O	D
FSQRT	DRn	×	×	×	×	O	D
FSUB	DRm,DRn	×	×	×	×	O	D
FTRV	XMTRX,FVn	×	×	×	O	×	S

Table 3-9 SH-4 Executable Instruction and Operation Size Combinations (Part 3)

3. System Control Instructions Operation Sizes

Mnemonic	Addressing Mode	B	W	L	S	D	Default when Omitted
FCNVDS	DRm,FPUL	×	×	×	×	O	D
FCNVSD	FPUL,DRn	×	×	×	×	O	D
FLOAT	FPUL,DRn	×	×	×	×	O	D
FRCHG	(no operands)	×	×	×	×	×	—
FSCHG	(no operands)	×	×	×	×	×	—
FTRC	DRm,FPUL	×	×	×	×	O	D
LDC	Rm,DBR	×	×	O	×	×	L
LDC	@Rm+,DBR	×	×	O	×	×	L
OCBI	@Rn	×	×	×	×	O	—
OCBP	@Rn	×	×	×	×	O	—
OCBWB	@Rn	×	×	×	×	O	—
STC	DBR,Rn	×	×	O	×	×	L
STC	DBR,@-Rn	×	×	O	×	×	L
STC	SGR,Rn	×	×	O	×	×	L
STC	SGR,@-Rn	×	×	O	×	×	L

SH-DSP, SH3-DSP Executable Instruction and Operation Size Combinations:

Table 3-10 shows the executable instruction and operation size combinations for the SH-DSP and SH3-DSP instructions added to those of the SH-2 and SH-3, respectively.

Table 3-10 SH-DSP, SH3-DSP Executable Instruction and Operation Size Combinations (Part 1)

1. Repeat Control Instructions **Operation Sizes**

Mnemonic	Addressing Mode	B	W	L	Default when Omitted
LDRS	@(disp,PC)	×	×	O	L
LDRS	symbol	×	×	O	L
LDRE	@(disp,PC)	×	×	O	L
LDRE	symbol	×	×	O	L
SETRC	Rn	×	×	×	—
SETRC	#imm	×	×	×	—

Symbol meanings:

MOD............................ Modulo register
RS............................... Repeat start register
RE............................... Repeat end register
DSR............................. DSP status register
A0................................ DSP data register (A0, X0, X1, Y0, or Y1 can be specified.)

Table 3-10 SH-DSP, SH3-DSP Executable Instruction and Operation Size Combinations (Part 2)

2. System Control Instructions		Operation Sizes			
Mnemonic	Addressing Mode	B	W	L	Default when Omitted
LDC	Rn,MOD	×	×	O	L
LDC	Rn,RS	×	×	O	L
LDC	Rn,RE	×	×	O	L
LDC	@Rn+,MOD	×	×	O	L
LDC	@Rn+,RS	×	×	O	L
LDC	@Rn+,RE	×	×	O	L
LDS	Rn,DSR	×	×	O	L
LDS	Rn,A0	×	×	O	L
LDS	@Rn+,DSR	×	×	O	L
LDS	@Rn+,A0	×	×	O	L
STC	MOD,Rn	×	×	O	L
STC	RS,Rn	×	×	O	L
STC	RE,Rn	×	×	O	L
STC	MOD,@–Rn	×	×	O	L
STC	RS,@–Rn	×	×	O	L
STC	RE,@–Rn	×	×	O	L
STS	DSR,Rn	×	×	O	L
STS	A0,Rn	×	×	O	L
STS	DSR,@–Rn	×	×	O	L
STS	A0,@–Rn	×	×	O	L

3.2.2 Notes on Delayed Branch Instructions

The unconditional branch instructions are delayed branch instructions. The microprocessors execute the delay slot instruction (the instruction directly following a branch instruction in memory) before executing the delayed branch instruction.

If an instruction inappropriate for a delay slot is specified, the assembler issues error number 150 or 151.

Table 3-11 shows the relationship between the delayed branch instructions and the delay slot instructions.

Table 3-11 Relationship between Delayed Branch Instructions and Delay Slot Instructions

Delay Slot		Delayed Branch BF/S	BT/S	BRAF	BSRF	BRA	BSR	JMP	JSR	RTS	RTE
BF		×	×	×	×	×	×	×	×	×	×
BT		×	×	×	×	×	×	×	×	×	×
BF/S		×	×	×	×	×	×	×	×	×	×
BT/S		×	×	×	×	×	×	×	×	×	×
BRAF		×	×	×	×	×	×	×	×	×	×
BSRF		×	×	×	×	×	×	×	×	×	×
BRA		×	×	×	×	×	×	×	×	×	×
BSR		×	×	×	×	×	×	×	×	×	×
JMP		×	×	×	×	×	×	×	×	×	×
JSR		×	×	×	×	×	×	×	×	×	×
RTS		×	×	×	×	×	×	×	×	×	×
RTE		×	×	×	×	×	×	×	×	×	×
TRAPA		×	×	×	×	×	×	×	×	×	×
LDC	Rn,SR	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1
	@Rn+,SR	*1	*1	*1	*1	*1	*1	*1	*1	*1	*1
MOV	@(disp,PC),Rn	*2	*2	*2	*2	*2	*2	*2	*2	*2	*2
	symbol,Rn	*2	*2	×	×	*2	*2	×	×	×	×
MOVA	@(disp,PC),R0	*2	*2	*2	*2	*2	*2	*2	*2	*2	*2
	symbol,R0	*2	*2	×	×	*2	*2	×	×	×	×
Extended instructions	MOV.L #imm,Rn	×	×	×	×	×	×	×	×	×	×
	MOV.W #imm,Rn	×	×	×	×	×	×	×	×	×	×
	MOVA #imm,R0	×	×	×	×	×	×	×	×	×	×
Any other instruction		O	O	O	O	O	O	O	O	O	O

Symbol meanings:

O ..... Normal, i.e., the assembler generates the specified object code.

×...... Error 150 or 151
The instruction specified is inappropriate as a delay slot instruction.
The assembler generates object code with a NOP instruction (H'0009).

Notes: 1. Operates normally when the CPU type is SH-1, SH-2, SH-2E, or SH-DSP. Any other CPU type will cause error 150 or 151 to occur.

2. When the CPU type is SH-4, error 150 or 151 occurs. Any other CPU type will cause warning 871 to occur.
Note on the value of PC: PC = <destination address for the delayed branch instruction> + 2
The assembler generates the specified object code.

CAUTION!

If the delayed branch instruction and the delay slot instruction are coded in different sections, the assembler does not check the validity of the delay slot instruction.

Reference:

Extended Instructions
  → Programmer's Guide, 9.2, "Extended Instructions Related to Automatic Literal Pool Generation"

3.2.3 Notes on Address Calculations

When the operand addressing mode is PC relative with displacement, i.e., @(disp,PC), the value of PC must be taken into account in coding. The value of PC can vary depending on certain conditions.

(1) Normal Case

The value of PC is <u>the first address in the currently executing instruction plus 4 bytes.</u>

Examples: (Consider the state when a MOV instruction is being executed at absolute address H'00001000.)

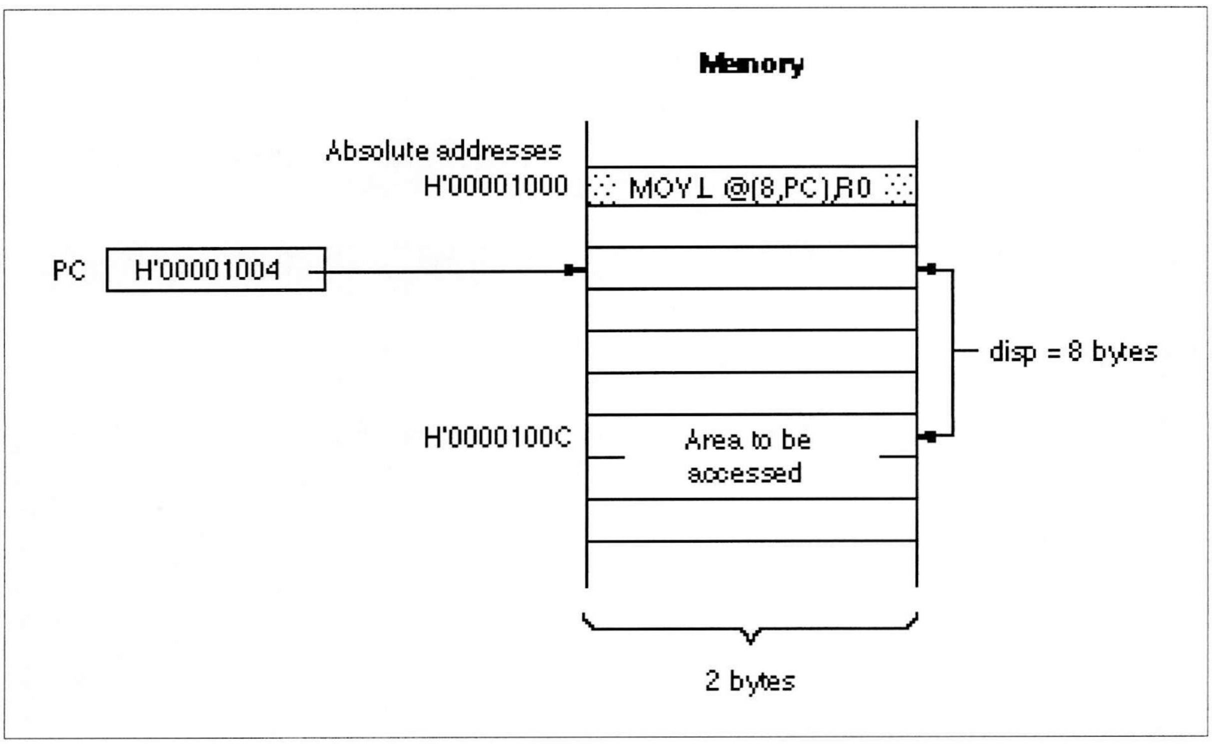


Figure 3-1 Address Calculation Example (Normal Case)

(2) During the Delay Slot Instruction

The value of PC is destination address for the delayed branch instruction plus 2 bytes.

Examples: (Consider the state when a MOV instruction is being executed at absolute address H'00001000.)

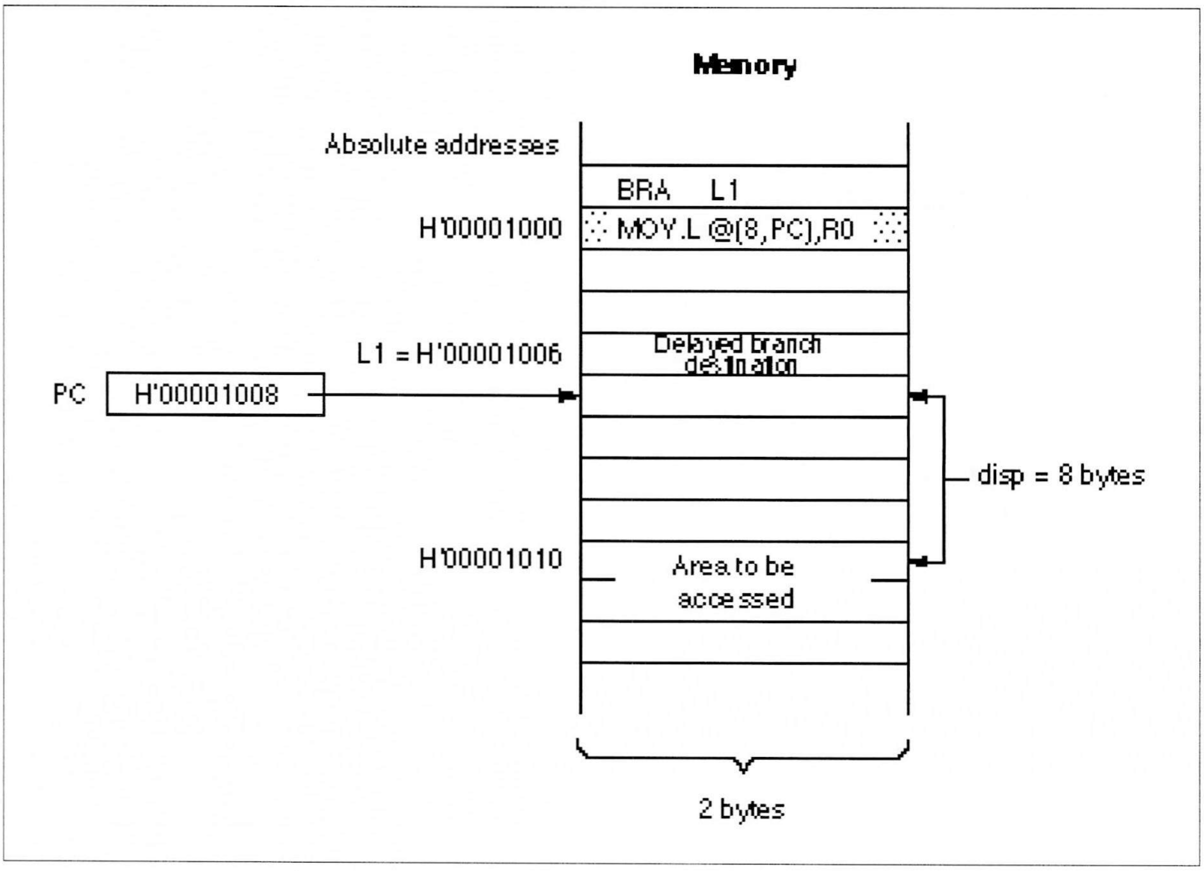


Figure 3-2 Address Calculation Example (When the Value of PC Differs Due to a Branch)

Supplement:

When the operand is the PC relative specified with the symbol, the assembler derives the displacement taking account of the value of PC when generating the object code.

(3) During the Execution of Either a MOV.L @(disp,PC),Rn or a MOVA @(disp,PC),R0

When the value of PC is not a multiple of 4, microprocessors correct the value by discarding the lower 2 bits when calculating addresses.

Examples: 1. When the microprocessor corrects the value of PC
(Consider the state when a MOV instruction is being executed at address H'00001002.)

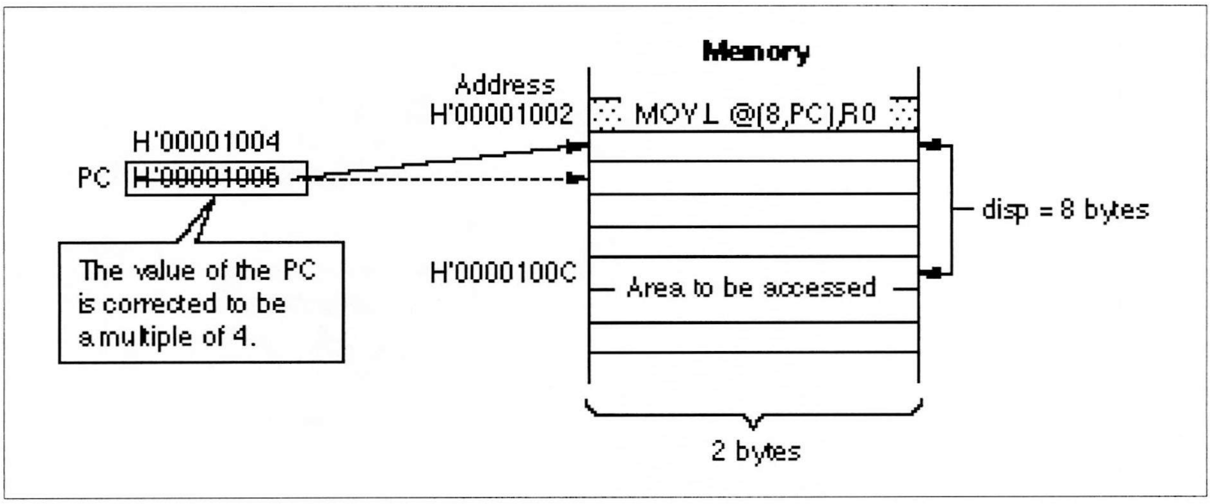


Figure 3-3 Address Calculation Example (When Microprocessor Corrects the Value of PC)

2. When the microprocessor does not correct the value of PC
(Consider the state when a MOV instruction is being executed at address H'00001000.)

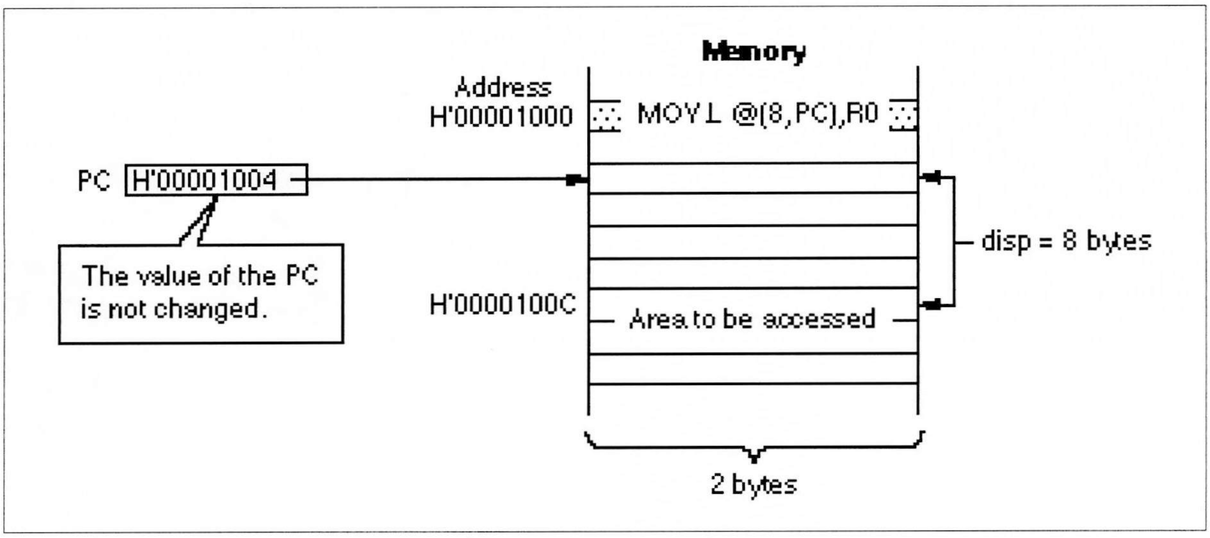


Figure 3-4 Address Calculation Example (When Microprocessor Does Not Correct the Value of PC)

Supplement:

When the operand is the PC relative specified with the symbol, the assembler derives the displacement taking account of the value of PC when generating the object code.

Section 4 DSP Instructions

4.1 Program Contents

4.1.1 Source Statements

The SH-DSP instructions are classified into two types: executable instructions and DSP instructions. The DSP instructions manipulate DSP registers. The instruction set and description format of DSP instructions are different from those of the executable instructions. For the DSP instructions, many operations can be included in one statement. The DSP instruction operation is as follows:

1. DSP operation: Specifies operations between DSP registers.

   PABS, PADD, PADDC, PAND, PCLR, PCMP, PCOPY, PDEC, PDMSB, PINC, PLDS, PMULS, PNEG, POR, PRND, PSHA, PSHL, PSTS, PSUB, PSUBC, PXOR

2. X data transfer operation: Specifies data transfer between a DSP register and X data memory.

   MOVX, NOPX

3. Y data transfer operation: Specifies data transfer between a DSP register and Y data memory.

   MOVY, NOPY

4. Single data transfer operation: Specifies data transfer between a DSP register and memory.

   MOVS

Reference:

Executable instructions
    → Programmer's Guide, 3, "Executable Instructions"

4.1.2 Parallel Operation Instructions

Parallel operation instructions specify DSP operations as well as data transfer between a DSP register and X or Y data memory at the same time. The instruction size is 32 bits. The description format is as follows:

```
[<label>] [ <DSP operation part>] [ <data transfer part>] [<comment>]
```

DSP Operation Part Description Format:

```
[<condition> ]<DSP operation> <operand>[ <DSP operation> <operand>]
```

- Condition: Specifies how parallel operation instruction is executed as follows:

  DCT: The instruction is executed when the DC bit is 1.
  DCF: The instruction is executed when the DC bit is 0.

- DSP operation: Specifies DSP operation.

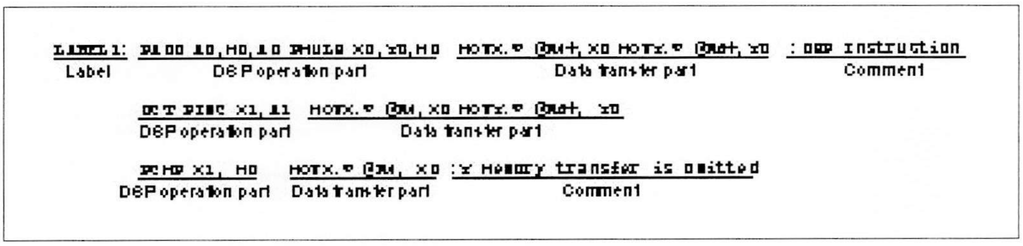
  PADD and PMULS, and PSUB and PMULS can be specified in combination.

Data Transfer Part Description Format:

```
[<X data transfer operation>[ <operand>]]
                              [ <Y data transfer operation>[ <operand>]]
```

Be sure to specify X data transfer and Y data transfer in this order. Inputting an instruction is not required when the data move instruction is NOPX or NOPY.

Example:



4.1.3 Data Move Instructions

Two types of data move instructions are available: combination of X data memory transfer and Y data memory transfer, and single data transfer. The description formats are as follows:

Combination of X Data Memory Move and Y Data Memory Move Instructions:

```
[<label>] [ <X data transfer operation>[ <operand>]]
               [ <Y data transfer operation>[ <operand>]] [<comment>]
```

Be sure to specify X data memory transfer and Y data memory transfer in this order. Inputting an instruction is not required when the data move instruction is NOPX or NOPY. Note that both X data memory and Y data memory cannot be omitted, unlike the parallel operation instruction.

Example:

```
LABEL2:  MOVX.W @R4,X0                ; Data move instruction
                                        (Y data memory transfer is omitted)
         MOVX.W @R4,X0 MOVY.W @R6+, Y0
```

Single Data Move Instruction:

```
[<label>] [ <single data transfer operation> <operand>] [<comment>]
```

Specifies the MOVS instruction.

Example:

```
LABEL3:     MOVS.W @-R2,A0      ; Single data transfer
```

4.1.4 Coding of Source Statements Across Multiple Lines

For the DSP instructions, many operations can be included in one statement, and therefore, source statements become long and complicated. To make programs easy to read, source statements for DSP instructions can be written across multiple lines by separating between an operand and an operation, in addition to separating at a comma between operands.

Write source statements across multiple lines using the following procedure.

1. Insert a new line between an operand and an operation.
2. Insert a plus sign (+) in the first column of the new line.
3. Continue writing the source statement following the plus sign.

Spaces and tabs can be inserted following the plus sign.

Example:

```
        PADD    A0,M0,X0
+       PMULS   A1,Y1,M0
+       MOVX    @R4,x0
+       MOVY    @R6,Y1

; A single source statement is written across four lines.
```

4.2 DSP Instructions

4.2.1 DSP Operation Instructions

Table 4-1 lists DSP instructions in mnemonic.

Table 4-1 DSP Instructions in Mnemonic

Instruction Name	Mnemonic
DSP arithmetic operation instructions	PADD, PSUB, PCOPY, PDMSB, PINC, PNEG, PMULS, PADDC, PSUBC, PCMP, PDEC, PABS, PRND, PCLR, PLDS, PSTS
DSP logic operation instructions	POR, PAND, PXOR
DSP shift operation instructions	PSHA, PSHL

Operation Size:

For the DSP operation instructions, operation size cannot be specified.

Addressing Mode:

Table 4-2 lists addressing modes for the DSP operation instructions.

Table 4-2 Addressing Modes for DSP Operation Instructions

Addressing Mode	Description Format
DSP register direct	Dp (DSP register name)
Immediate data	#imm

- DSP register direct

Table 4-3 lists registers that can be specified in DSP register direct addressing mode. For Sx, Sy, Dz, Du, Se, Sf, and Dg, refer to table 4-5, DSP Operation Instructions.

Table 4-3 Registers that Can Be Specified in DSP Register Direct Addressing Mode

		DSP Register							
		A0	**A1**	**M0**	**M1**	**X0**	**X1**	**Y0**	**Y1**
Dp	Sx	Yes	Yes			Yes	Yes		
	Sy			Yes	Yes			Yes	Yes
	Dz	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Du	Yes	Yes			Yes		Yes	
	Se		Yes			Yes	Yes	Yes	
	Sf		Yes			Yes		Yes	Yes
	Dg	Yes	Yes	Yes	Yes				

- Immediate data

Immediate data can be specified for the first operand of the PSHA and PSHL instructions. The following items can be specified:

— Value type
Constants, symbols, or expressions can be specified.

— Symbol types
Symbols including relative and import symbols can be specified as immediate data.*

— Value range
Table 4-4 lists the specifiable value ranges.

Table 4-4 Ranges of Immediate Data

Instruction	Range
PSHA instruction	H'FFFFFFE0 to H'00000020 (–32 to 32)
PSHL instruction	H'FFFFFFF0 to H'00000010 (–16 to 16)

Note: When a relative symbol or import symbol is specified as immediate data, the linkage editor checks the value in the rage from H'FFFFFFC0 to H'0000003F (–64 to 63).

Combination of Multiple DSP Operation Instructions:

The PADD instruction and the PMULS instruction, or the PSUB instruction and the PMULS instruction can be specified in combination. Each of these two combinations is basically one DSP instruction. The PADD (or PSUB) operand and a PMULS operand are separately described so that programs can be read easily.

Example:

```
PADD A0,M0,A0 PMULS X0,Y0,M0 NOPX MOVY.W @R6+, Y0
PSUB A1,M1,A1 PMULS X1,Y1,M1 MOVX @R4+,X0 NOPY
```

Note: Warning 701 is displayed if the same register is specified as the destination registers when multiple DSP operation instructions are specified in combination.

Example:

```
PADD A0,M0,A0 PMULS X0,Y0,A0   → Warning 701
```

Conditional DSP Operation Instructions:

Conditional DSP operation instructions specify if the program is executed according to the DC bit of the DSR register.

DCT: When the DC bit is 1, the instruction is executed.
DCF: When the DC bit is 0, the instruction is executed.

Conditional DSP operation instructions are the following:

PADD, PAND, PCLR, PCOPY, PDEC, PDMSB, PINC, PLDS, PNEG, POR, PSHA, PSHL, PSTS, PSUB, PXOR

DSP Operation Instruction List:

Table 4-5 lists DSP operation instructions. For the registers that can be specified as Sx, Sy, Dz, Du, Se, Sf, and Dg, refer to table 4-3, Registers that Can Be Specified in DSP Register Direct Addressing Mode.

Table 4-5 DSP Operation Instructions

Mnemonic	Addressing Mode	Mnemonic	Addressing Mode
PABS	Sx, Dz		
PABS	Sx, Dz		
PADD	Sx, Sy, Dz		
PADD	Sx, Sy, Du	PMULS	Se, Sf, Dg
PADDC	Sx, Sy, Dz		
PAND	Sx, Sy, Dz		
PCLR	Dz		
PCMP	Sx, Sy		
PCOPY	Sx, Dz		
PCOPY	Sy, Dz		
PDEC	Sx, Dz		
PDEC	Sy, Dz		
PDMSB	Sx, Dz		
PDMSB	Sy, Dz		
PINC	Sx, Dz		
PINC	Sy, Dz		
PLDS	Dz, MACH		
PLDS	Dz, MACL		
PMULS	Se, Sf, Dg		
PNEG	Sx, Dz		
PNEG	Sy, Dz		
POR	Sx, Sy, Dz		
PRND	Sx, Dz		
PRND	Sy, Dz		
PSHA	#imm, Dz		
PSHA	Sx, Sy, Dz		
PSHL	#imm, Dz		
PSHL	Sx, Sy, Dz		
PSTS	MACH, Dz		

Table 4-5 DSP Operation Instructions (cont)

Mnemonic	Addressing Mode	Mnemonic	Addressing Mode
PSTS	MACL, Dz		

PSUB	Sx, Sy, Dz		
PSUB	Sx, Sy, Du	PMULS	Se, Sf, Dg
PSUBC	Sx, Sy, Dz		
PXOR	Sx, Sy, Dz		

4.2.2 Data Move Instructions

Mnemonics:

Two types of data move instructions are available: dual memory move instructions and single memory move instructions.

Dual memory move instructions specify data move, at the same time, between x memory and a DSP register, and between Y memory and a DSP register.

Single memory move instructions specify data move between arbitrary memory and a DSP register. Table 4-6 lists data move instructions in mnemonic.

Table 4-6 Data Move Instructions in Mnemonic

Classification		Mnemonic
Dual memory move	X memory move	NOPX MOVX
	Y memory move	NOPY MOVY
Single memory move		MOVS

Operation Size:

NOPX and NOPY instructions: Operation size cannot be specified.

MOVX and MOVY instructions: Only word size (.W) can be specified. If omitted, word size is specified.

MOVS instruction: Word size (.W) or longword size (.L) can be specified. If omitted, longword size is specified.

Addressing Mode:

Table 4-7 lists addressing modes that can be specified for the data move instructions.

Table 4-7 Addressing Modes of Data Move Instructions

Addressing mode	Description
DSP register direct	Dz
Register indirect	@Az
Register indirect with post-increment	@Az+
Register indirect with index/post-increment	@Az+Iz
Register indirect with pre-decrement	@-Az

Register indirect with index/post-increment is a special addressing mode for the DSP data move instructions. In this mode, after referring to the contents indicated by register Az, register Az contents are incremented by the value of the Iz register.

Registers that Can Be Specified in Addressing Modes:

Table 4-8 lists registers that can be specified in the DSP register direct, register indirect, register indirect with post-increment, register indirect with index/post-increment, and register indirect with pre-decrement addressing modes. For Dx, Dy, Ds, Da, Ax, Ay, As, Ix, Iy, and Is, refer to table 4-9, Data Move Instructions.

Table 4-8 Registers that Can Be Specified in Addressing Modes for Data Move Instructions

		General Register								DSP Register									
		R2	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**A0**	**A1**	**M0**	**M1**	**X0**	**X1**	**Y0**	**Y1**	**A0G**	**A1G**
Dz	Dx													Yes	Yes				
	Dy															Yes	Yes		
	Ds									Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Da									Yes	Yes								
Az	Ax			Yes	Yes														
	Ay					Yes	Yes												
	As	Yes	Yes	Yes	Yes														
Iz	Ix							Yes											
	Iy								Yes										
	Is							Yes											

Note: Warning 703 is displayed if the destination register for the DSP instruction and the destination register for the data move instruction are the same register, and if the instructions are in the same statement.

Example:

```
PADD A0,M0,Y0   NOPX   MOVY.W @R6+,Y0  → Warning 703
```

Data Move Instruction List:

Table 4-9 lists data move instructions. For registers that can be specified for Dx, Dy, Ds, Da, Ax, Ay, As, Ix, Iy, and Is, refer to table 4-8, Registers that Can Be Specified in Addressing Modes for Data Move Instructions.

Table 4-9 Data Move Instructions

Classification	Mnemonic	Addressing Mode
X data move instructions	NOPX	
	MOVX.W	@Ax, Dx
	MOVX.W	@Ax+, Dx
	MOVX.W	@Ax+Ix, Dx
	MOVX.W	Da, @Ax
	MOVX.W	Da, @Ax+
	MOVX.W	Da, @Ax+Ix
Y data move instructions	NOPY	
	MOVY.W	@Ay, Dy
	MOVY.W	@Ay+, Dy
	MOVY.W	@Ay+Iy, Dy
	MOVY.W	Da, @Ay
	MOVY.W	Da, @Ay+
	MOVY.W	Da, @Ay+Iy
Single data move instructions	MOVS.W	@-As, Ds
	MOVS.W	@As, Ds
	MOVS.W	@As+, Ds
	MOVS.W	@As+Is, Ds
	MOVS.W	Ds, @-As
	MOVS.W	Ds, @As
	MOVS.W	Ds, @As+
	MOVS.W	Ds, @As+Is
	MOVS.L	@-As, Ds
	MOVS.L	@As, Ds
	MOVS.L	@As+, Ds
	MOVS.L	@As+Is, Ds
	MOVS.L	Ds, @-As
	MOVS.L	Ds, @As
	MOVS.L	Ds, @As+
	MOVS.L	Ds, @As+Is

Section 5 Assembler Directives

5.1 Overview of the Assembler Directives

The assembler directives are instructions that the assembler interprets and executes. Table 5-1 lists the assembler directives provided by this assembler.

Table 5-1 Assembler Directives

Type	Mnemonic	Function
Target CPU	.CPU	Specifies the target CPU.
Section and the location counter	.SECTION	Declares a section.
	.ORG	Sets the value of the location counter.
	.ALIGN	Corrects the value of the location counter.
Symbols	.EQU	Sets a symbol value (reset not allowed).
	.ASSIGN	Sets a symbol value (reset allowed).
	.REG	Defines the alias of a register name.
	.FREG	Defines a floating-point register name.
Data and data area reservation	.DATA	Reserves integer data.
	.DATAB	Reserves integer data blocks.
	.SDATA	Reserves character string data.
	.SDATAB	Reserves character string data blocks.
	.SDATAC	Reserves character string data (with length).
	.SDATAZ	Reserves character string data (with zero terminator).
	.FDATA	Reserves floating-point data.
	.FDATAB	Reserves floating-point data blocks.
	.XDATA	Reserves fixed-point data.
	.RES	Reserves data area.
	.SRES	Reserves character string data area.
	.SRESC	Reserves character string data area (with length).
	.SRESZ	Reserves character string data area (with zero terminator).
	.FRES	Reserves floating-point data area.

Table 5-1 Assembler Directives (cont)

Type	Mnemonic	Function
Export and import symbol	.EXPORT	Declares export symbols.
	.IMPORT	Declares import symbols.
	.GLOBAL	Declares export and import symbols.
Object modules	.OUTPUT	Controls object module output.
	.DEBUG	Controls the output of symbolic debug information.
	.ENDIAN	Selects big endian or little endian.
	.LINE	Changes line number.
Assemble listing	.PRINT	Controls assemble listing output.
	.LIST	Controls the output of the source program listing.
	.FORM	Sets the number of lines and columns in the assemble listing.
	.HEADING	Sets the header for the source program listing.
	.PAGE	Inserts a new page in the source program listing.
	.SPACE	Outputs blank lines to the source program listing.
Other directives	.PROGRAM	Sets the name of the object module.
	.RADIX	Sets the radix in which integer constants with no radix specifier are interpreted.
	.END	Declares the end of the source program.

5.2 Assembler Directive Reference

5.2.1 Target CPU Assembler Directive

This assemble provides the following assembler directive concerned with the target CPU.

.CPU

Specifies the target CPU.

.CPU

Target CPU Specification

Syntax

```
.CPU <target CPU>
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .CPU mnemonic.

3. Operands

   Enter the target CPU.

Specification	Target CPU
SH1	Assembles program for SH-1
SH2	Assembles program for SH-2
SH2E	Assembles program for SH-2E
SH3	Assembles program for SH-3
SH3E	Assembles program for SH-3E
SH4	Assembles program for SH-4
SHDSP	Assembles program for SH-DSP
SH3DSP	Assembles program for SH3-DSP

This directive determines the target CPU. If it is omitted, the CPU specified by the SHCPU environment variable becomes valid.

Reference: SHCPU environment variable
→ User's Guide, 1.3, "SHCPU Environment Variable"

Description

1. .CPU is the assembler directive that specifies the target CPU for which the source program is assembled.

2. The following CPUs can be selected:

   - SH1 (for SH-1)
   - SH2 (for SH-2)
   - SH2E (for SH-2E)
   - SH3 (for SH-3)
   - SH3E (for SH-3E)
   - SH4 (for SH-4)
   - SHDSP (for SH-DSP)
   - SH3DSP (for SH3-DSP)

3. Specify this directive at the beginning of the source program. If it is not specified at the beginning, an error will occur. However, directives related to assembly listing can be written before this directive.

4. When several .CPU directives are specified, only the first specification becomes valid.

5. The assembler gives priority to target CPU specification in the order of –CPU, .CPU, and the SHCPU environment variable.

Coding Example

```
.CPU    SH2

.SECTION A,CODE,ALIGN=4
MOV.L R0,R1
MOV.L R0,R2
```

Assembles program for SH-2.

Reference: –CPU
→ User's Guide, 2.2.1, "CPU Command Line Option" –CPU

5.2.2 Section and Location Counter Assembler Directives

This assembler provides the following assembler directives concerned with sections and the location counter.

.SECTION

Declares a section.

.ORG

Sets the value of the location counter.

.ALIGN

Adjusts the value of the location counter to a multiple of the boundary alignment value.

Section Declaration

Syntax

```
.SECTION <section name> [,<section attribute>
  [,{LOCATE= <start address>|ALIGN=<boundary alignment value>}]]
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .SECTION mnemonic.

3. Operands

   — First operand: the section name
   The rules for section names are the same as the rules for symbols.

   References: Naming sections
   → Programmer's Guide, 1.3.2, "Coding of Symbols"

   — Second operand: the section attribute

Attribute	Section Type
CODE	Code section
DATA	Data section
STACK	Stack section
COMMON	Common section
DUMMY	Dummy section

The shaded section indicates the default value when the specifier is omitted.

When the specification is omitted, the section will be a code section.

— Third operand: start address or boundary alignment value

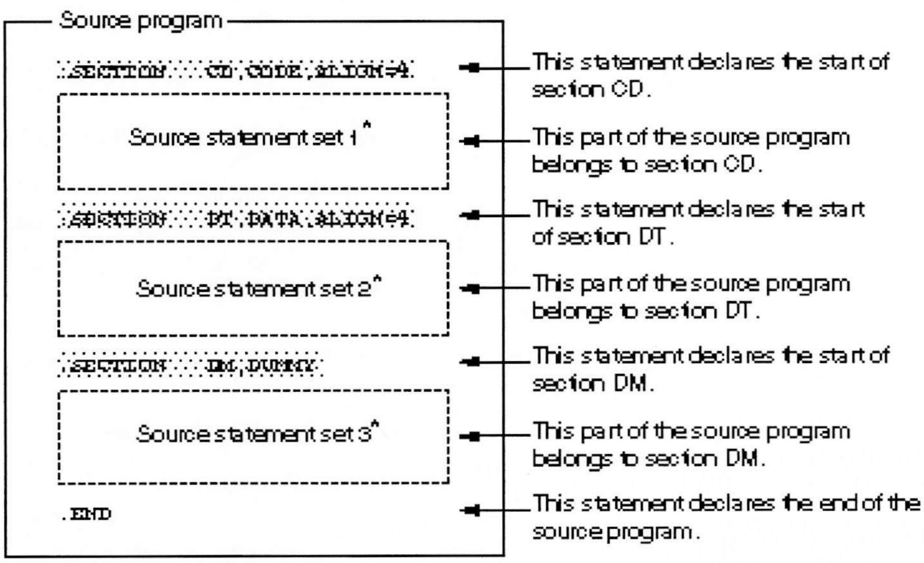
Specification	Section Type
LOCATE = <start address>	Absolute address section
ALIGN = <boundary alignment value>	Relative address section
No specification	Relative address section (boundary alignment value = 4)

The specification determines whether the section type will be an absolute address section or a relative address section.

Description

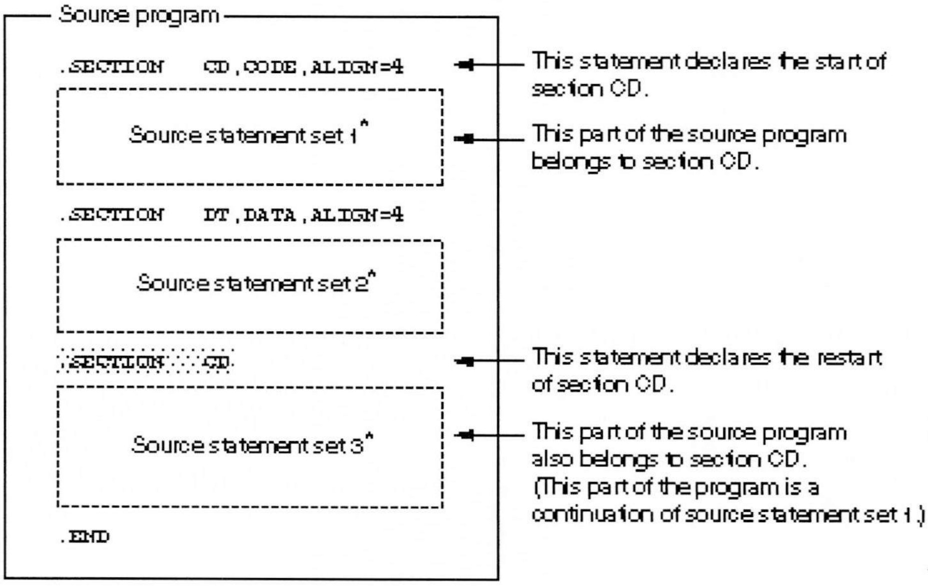
1. .SECTION is the section declaration assembler directive.

   A section is a part of a program, and the linkage editor regards it as a unit of processing. The following describes section declaration using the simple examples shown below.



Note: This example assumes that the .SECTION directive does not appear in any of the source statement sets 1 to 3.

2. It is possible to redeclare (and thus restart, i.e., re-enter) a section that was previously declared in the same file. The following is a simple example of section restart.



Note: This example assumes that the .SECTION directive does not appear in any of the source statement sets 1 to 3.

CAUTION!

When using the .SECTION directive to restart a section, the second and third operands must be omitted. (The original specifications when first declaring the section remain valid.)

3. Use LOCATE = <start address> as the third operand when starting an absolute address section. The start address is the absolute address of the start of that section.

   The start address must be specified as follows:

   — The specification must be an absolute value,
   and,
   — Forward reference symbols must not appear in the specification.

   The values allowed for the start address are from H'00000000 to H'FFFFFFFF. (From 0 to 4,294,967,295 in decimal.)

4. Use ALIGN = <boundary alignment value> to start a relative address section. The linkage editor will adjust the start address of the section to be a multiple of the boundary alignment value.

   The boundary alignment value must be specified as follows:

   — The specification must be an absolute value,

     and,

   — Forward reference symbols must not appear in the specification.

   The values allowed for the boundary alignment value are powers of 2, e.g. 2^0, 2^1, 2^2, ..., 2^{31}. For code sections, the values must be 4 or larger powers of 2, e.g. 2^2, 2^3, 2^4, ..., 2^{31}.

5. The assembler provides a default section for the following cases:

   — The use of executable or extended instructions when no section has been declared.
   — The use of data reservation assembler directives when no section has been declared.
   — The use of the .ALIGN directive when no section has been declared.
   — The use of the .ORG directive when no section has been declared.
   — Reference to the location counter when no section has been declared.
   — The use of statements consisting of only the label field when no section has been declared.

   The default section is the following section:

   — Section name: P
   — Section type: Code section
     Relative address section (with a boundary alignment value of 4)

Coding Example

```
          .ALIGN      4               ; This section of the program belongs to the default section P.
          .DATA.L     H'11111111      ; The default section P is a code section, and is a relative
             ~                        ; address section with a boundary alignment value of 4.

      .SECTION CD,CODE,ALIGN=4

          MOV         R0,R1           ; This section of the program belongs to the section CD.
          MOV         R0,R2           ; The section CD is a code section, and is a relative address
             ~                        ; section with a boundary alignment value of 4.

      .SECTION DT,DATA,LOCATE=H'00001000

  X1:     .DATA.L     H'22222222      ; This section of the program belongs to the section DT.
          .DATA.L     H'33333333      ; The section DT is a data section, and is an absolute address
             ~                        ; section with a start address of H'00001000.

          .END
```

Note: This example assumes the .SECTION directive does not appear in the parts indicated by "~".

.ORG

Location-Counter-Value Setting

Syntax

```
.ORG <location-counter-value>
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .ORG mnemonic.

3. Operands

   Enter the new value for the location counter.

Description

1. .ORG is the assembler directive that sets the value of the location counter. The .ORG directive is used to place executable instructions or data at a specific address.

2. The location-counter-value must be specified as follows:

   — The specification must be an absolute value or an address within the section, and,
   — Forward reference symbols must not appear in the specification.

   The values allowed for the location-counter-value are from H'00000000 to H'FFFFFFFF. (From 0 to 4,294,967,295 in decimal.)

   When the location-counter-value is specified with an absolute value, the following condition must be satisfied:

   <location-counter-value>   <section start address> (when compared as unsigned values)

3. The assembler handles the value of the location counter as follows:

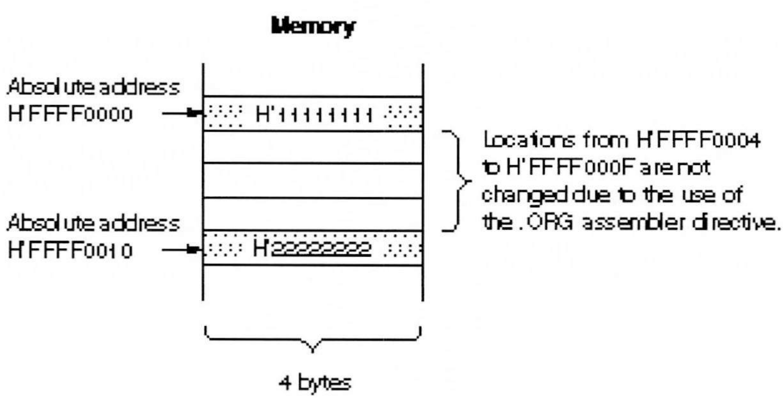
   — The value is regarded as an absolute address value within an absolute address section.

   — The value is regarded as a relative address value (relative distance from the section head) within a relative address section.

Coding Example

```
        .SECTION    DT,DATA,LOCATE=H'FFFF0000
        .DATA.L     H'11111111
        .ORG        H'FFFF0010     ; This statement sets the value of the location
                                   ; counter.
        .DATA.L     H'22222222     ; The integer data H'22222222 is stored at
                                   ; absolute address H'FFFF0010.
          ~
```

Explanatory Figure for the Coding Example



```
.ALIGN
```

Location-Counter-Value Correction

Syntax

```
.ALIGN <boundary alignment value>
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .ALIGN mnemonic.

3. Operands

   Enter the boundary alignment value.

Description

1. .ALIGN is the assembler directive that corrects the location-counter-value to be a multiple of the boundary alignment value. Executable instructions and data can be allocated on specific boundary values (address multiples) by using the .ALIGN directive.

2. The boundary alignment value must be specified as follows:

   — The specification must be an absolute value,

   and,

   — Forward reference symbols must not appear in the specification.

   The values allowed for the boundary alignment value are powers of 2, e.g. 2^0, 2^1, 2^2, ..., 2^{31}.

3. When .ALIGN is used in a relative section the following must be satisfied:

   Boundary alignment value specified by .SECTION $\geq$ Boundary alignment value specified by .ALIGN

4. When .ALIGN is used in a code section, the assembler inserts NOP instructions in the object code* to adjust the value of the location counter. Odd byte size areas are filled with H'09.

   Note: This object code is not displayed in the assemble listing.

   When .ALIGN is used in a data, dummy, or stack section, the assembler only adjusts the value of the location counter, and does not fill in any object code in memory.

Coding Example

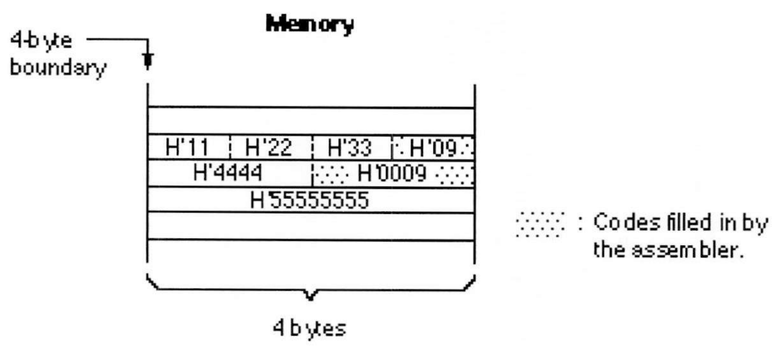
```
.SECTION    P,code
    ~
.DATA.B     H'11
.DATA.B     H'22
.DATA.B     H'33

.ALIGN      2             ; This statement adjusts the value of the location
.DATA.W     H'4444        ; counter to be a multiple of 2.

.ALIGN      4             ; This statement adjusts the value of the location
.DATA.L     H'55555555    ; counter to be a multiple of 4.
    ~
```

Explanatory Figure for the Coding Example

This example assumes that the byte-sized integer data H'11 is originally located at the 4-byte boundary address. The assembler will insert the filler data as shown in the figure below.



5.2.3 Symbol Handling Assembler Directives

This assembler provides the following assembler directives concerned with symbols.

.EQU

Sets a symbol value.

.ASSIGN

Sets and resets a symbol value.

.REG

Defines the alias of a register name.

.FREG

Defines a floating-point register name.

Symbol Value Setting (Resetting Not Allowed)

Syntax

```
<symbol>[:] .EQU <symbol value>
```

Statement Elements

1. Label

   Enter the symbol to which a value is to be set.

2. Operation

   Enter the .EQU mnemonic.

3. Operands

   Enter the value to be set to the symbol.

Description

1. .EQU is the assembler directive that sets a value to a symbol.

   Symbols defined with the .EQU directive cannot be redefined.

2. The symbol value must be specified as follows:

   — The specification must be an absolute value, an address value, or an import symbol value* and,
   — Forward reference symbols must not appear in the specification.

   The values allowed for the symbol value are from H'00000000 to H'FFFFFFFF.
   (From -2,147,483,648 to 4,294,967,295 in decimal.)

   Note: An import value, import value + constant, or import value – constant can be specified.

Coding Example

```
        ~

X1:     .EQU     10        ; The value 10 is set to X1.
X2:     .EQU     20        ; The value 20 is set to X2.

        CMP/EQ   #X1,R0    ; This is the same as CMP/EQ #10,R0.
        BT       LABEL1
        CMP/EQ   #X2,R0    ; This is the same as CMP/EQ #20,R0.
        BT       LABEL2

        ~
```

Symbol Value Setting (Resetting Allowed)

Syntax

```
<symbol>[:] .ASSIGN <symbol value>
```

Statement Elements

1. Label

   Enter the symbol to which a value is to be set.

2. Operation

   Enter the .ASSIGN mnemonic.

3. Operands

   Enter the value to be set to the symbol.

Description

1. .ASSIGN is the assembler directive that sets a value to a symbol.

   Symbols defined with the .ASSIGN directive can be redefined with the .ASSIGN directive.

2. The symbol value must be specified as follows:

   — The specification must be an absolute value or an address value,
   and,
   — Forward reference symbols must not appear in the specification.

   The values allowed for the symbol value are from H'00000000 to H'FFFFFFFF. (From 0 to 4,294,967,295 in decimal.)

3. Definitions with the .ASSIGN directive are valid from the point of the definition forward in the program.

4. Symbols defined with .ASSIGN have the following limitations:

— They cannot be used as export or import symbols.
— They cannot be referenced from the debugger.

Coding Example

```
            ~

X1:     .ASSIGN   1
X2:     .ASSIGN   2
         CMP/EQ   #X1,R0     ; This is the same as CMP/EQ #1,R0.
         BT       LABEL1
         CMP/EQ   #X2,R0     ; This is the same as CMP/EQ #2,R0.
         BT       LABEL2

            ~

X1:     .ASSIGN   3
X2:     .ASSIGN   4
         CMP/EQ   #X1,R0     ; This is the same as CMP/EQ #3,R0.
         BT       LABEL3
         CMP/EQ   #X2,R0     ; This is the same as CMP/EQ #4,R0.
         BF       LABEL4

            ~
```

Register Name Alias Definition

Syntax

```
<symbol>[:]  .REG <register name>
   or
<symbol>[:]  .REG (<register name>)
```

Statement Elements

1. Label

   Enter the symbol to be defined as the alias of a register name.

2. Operation

   Enter the .REG mnemonic.

3. Operands

   Enter the register name for which the alias of a register name is being defined.

Description

1. .REG is the assembler directive that defines the alias of a register name.

   The alias of a register name defined with .REG can be used in exactly the same manner as the original register name.

   The alias of a register name defined with .REG cannot be redefined.

2. The alias of a register name can only be defined for the general registers (R0 to R15, and SP).

3. Definitions with the .REG directive are valid from the point of the definition forward in the program.

4. Symbols defined with .REG have the following limitations:

   — They cannot be used as import or export symbols.
   — They cannot be referenced from the simulator/debugger.

Coding Example

```
        ~

MIN:    .REG      R10
MAX:    .REG      R11

        MOV       #0,MIN      ; This is the same as MOV #0,R10.
        MOV       #99,MAX     ; This is the same as MOV #99,R11.

        CMP/HS    MIN,R1
        BF        LABEL
        CMP/HS    R1,MAX
        BF        LABEL

        ~
```

Floating-Point Register Name Alias Definition

Syntax

```
<symbol>[:] .FREG <floating-point register name>
   or
<symbol>[:] .FREG (<floating-point register name>)
```

Statement Elements

1. Label

   Enter the symbol to be defined as a floating-point register name.

2. Operation

   Enter the .FREG mnemonic.

3. Operands

   Enter the floating-point register name for which the alias is to be defined.

Description

1. .FREG is the assembler directive that defines the alias of a floating-point register name.

   The alias of a floating-point register name defined with .FREG can be used in exactly the same manner as the original register name.

   The alias of a floating-point register name defined with .FREG cannot be redefined.

2. The alias can only be defined for the floating-point registers FRm (m = 0 to 15), DRn (n = 0, 2, 4, 6, 8, 10, 12, 14), XDn (n = 0, 2, 4, 6, 8, 10, 12, 14), and FVi (i = 0, 4, 8, 12).

3. Definitions with the .FREG are valid from the point of the definition forward in the program.

4. Symbols defined with .FREG have the following limitations:

   — They cannot be used as import or export symbols.
   — They cannot be referenced from the simulator/debugger.

5. .FREG is valid only when SH-2E, SH-3E, or SH-4 is selected as the CPU type.

Coding Example

```
         ~

MAX:     .FREG      FR11
         FMOV       @FR1,MAX   ; This is the same as FMOV @FR1,FR11.

         FCMP/EQ    MAX,FR2    ; This is the same as FCMP/EQ FR11,FR2.
         BF         LABEL

         ~
```

5.2.4 Data and Data Area Reservation Assembler Directives

This assembler provides the following assembler directives that are concerned with data and data area reservation.

`.DATA`	Reserves integer data.
`.DATAB`	Reserves integer data blocks.
`.SDATA`	Reserves character string data.
`.SDATAB`	Reserves character string data blocks.
`.SDATAC`	Reserves character string data (with length).
`.SDATAZ`	Reserves character string data (with zero terminator).
`.FDATA`	Reserves floating-point data.
`.FDATAB`	Reserves floating-point data block.
`.XDATA`	Reserves fixed-point data.
`.RES`	Reserves data area.
`.SRES`	Reserves character string data area.
`.SRESC`	Reserves character string data area (with length).
`.SRESZ`	Reserves character string data area (with zero terminator).
`.FRES`	Reserves floating-point data area.

.DATA

Integer Data Reservation

Syntax

```
[<symbol>[:]]  .DATA[.<operation size>] <integer data>
                                         [,<integer data>...]
```

Statement Elements

1. Label

   Enter a reference symbol if required.

2. Operation

   — Mnemonic
   Enter .DATA mnemonic.

   — Operation size

Specifier	Data Size
B	Byte
W	Word (2 bytes)
L	Longword (4 bytes)

The shaded section indicates the default value when the specifier is omitted.

   The specifier determines the size of the reserved data.
   The longword size is used when the specifier is omitted.

3. Operands

   Enter the values to be reserved as data in the operand field.

Description

1. .DATA is the assembler directive that reserves integer data in memory.

2. Arbitrary values, including relative values and forward reference symbols, can be used to specify the integer data.

3. The range of values that can be specified as integer data varies with the operation size.

Operation Size	Integer Data Range*	
B	H'00000000 to H'000000FF H'FFFFFF80 to H'FFFFFFFF	(0 to 255) (–128 to –1)
W	H'00000000 to H'0000FFFF H'FFFF8000 to H'FFFFFFFF	(0 to 65,535) (–32,768 to –1)
L	H'00000000 to H'7FFFFFFF H'80000000 to H'FFFFFFFF	(0 to 4,294,967,295) (–2,147,483,648 to –1)

Note: Numbers in parentheses are decimal.

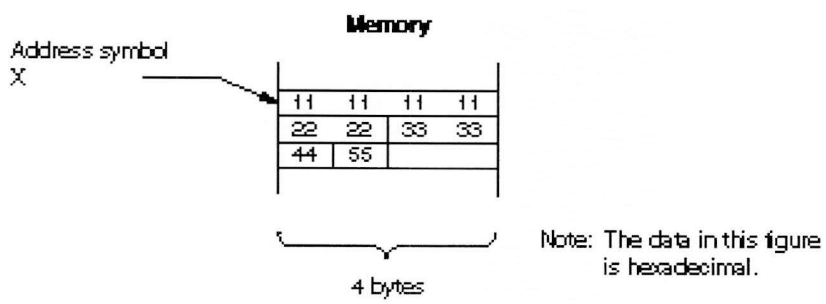
Coding Example

```
            ~

        .ALIGN     4               ; (This statement adjusts the value of the
                                     location counter.)
X:      .DATA.L    H'11111111      ;
        .DATA.W    H'2222,H'3333   ; These statements reserve integer data.
        .DATA.B    H'44,H'55       ;

            ~
```

Explanatory Figure for the Coding Example



.DATAB

Integer Data Block Reservation

Syntax

```
[<symbol>[:]] .DATAB[.<operation size>] <block count>,<integer data>
```

Statement Elements

1. Label

   Enter a reference symbol if required.

2. Operation

   — Mnemonic
   Enter .DATAB mnemonic.

   — Operation size

Specifier	Data Size
B	Byte
W	Word (2 bytes)
L	Longword (4 bytes)

The shaded section indicates the default value when the specifier is omitted.

The specifier determines the size of the reserved data.
The longword size is used when the specifier is omitted.

3. Operands

   — First operand: block count
   Enter the number of times the data value is repeated as the first operand.

   — Second operand: integer data
   Enter the value to be reserved as the second operand.

Description

1. .DATAB is the assembler directive that reserves the specified number of integer data items consecutively in memory.

2. The block count must be specified as follows:

   — The specification must be an absolute value,

   and,

   — Forward reference symbols must not appear in the specification.

   Arbitrary values, including relative values and forward reference symbols, can be used to specify the integer data.

3. The range of values that can be specified as the block size and as the integer data varies with the operation size.

Operation Size	Block Size Range*	
B	H'00000001 to H'FFFFFFFF	(1 to 4,294,967,295)
W	H'00000001 to H'7FFFFFFF	(1 to 2,147,483,647)
L	H'00000001 to H'3FFFFFFF	(1 to 1,073,741,823)

Operation Size	Integer Data Range*	
B	H'00000000 to H'000000FF H'FFFFFF80 to H'FFFFFFFF	(0 to 255) (–128 to –1)
W	H'00000000 to H'0000FFFF H'FFFF8000 to H'FFFFFFFF	(0 to 65,535) (–32,768 to –1)
L	H'00000000 to H'7FFFFFFF H'80000000 to H'FFFFFFFF	(0 to 4,294,967,295) (–2,147,483,648 to –1)

Note: Numbers in parentheses are decimal.

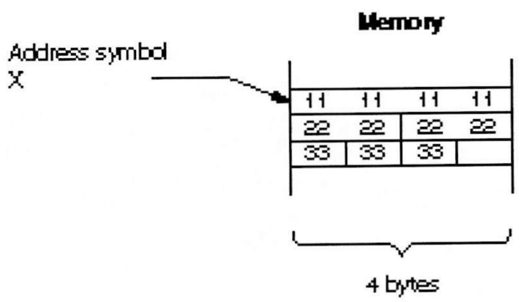
Coding Example

```
          ~

          .ALIGN      4               ; (This statement adjusts the value of the
                                      ; location counter.)
X:        .DATAB.L    1,H'11111111    ;
          .DATAB.W    2,H'2222        ; This statement reserves two blocks of integer
          .DATAB.B    3,H'33          ; data.

          ~
```

Explanatory Figure for the Coding Example



Note: The data in this figure is hexadecimal.

Character String Data Reservation

Syntax

```
[<symbol>[:]] .SDATA "<character string>"[,"<character string>"...]
```

Statement Elements

1. Label

   Enter a reference symbol if required.

2. Operation

   Enter the .SDATA mnemonic.

3. Operands

   Enter the character string(s) to be reserved.

Description

1. .SDATA is the assembler directive that reserves character string data in memory.

   Reference: Character strings → Programmer's Guide, 1.7, "Character Strings"

2. A control character can be appended to a character string.

   The syntax for this notation is as follows:

   ```
   "<character string>"<<ASCII code for a control character>>
   ```

   The ASCII code for a control character must be specified as follows:

   — The specification must be an absolute value,
     and,
   — Forward reference symbols must not appear in the specification.

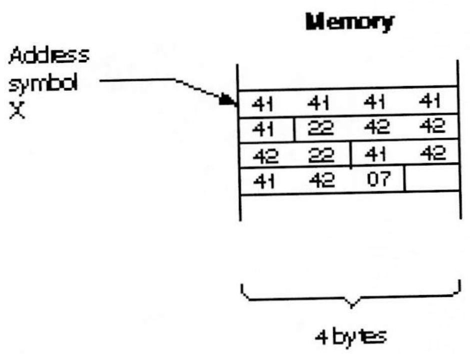
Coding Example

```
            ~

        .ALIGN      4               ; (This statement adjusts the value of
                                    ; the location counter.)
X:      .SDATA      "AAAAA"         ; This statement reserves character string data.
        .SDATA      """BBB"""       ; The character string in this example includes
                                    ; double quotation marks.
        .SDATA      "ABAB"<H'07>    ; The character string in this example has
                                    ; a control character appended.

            ~
```

Explanatory Figure for the Coding Example



Notes: 1. The data in this figure is hexadecimal.

2. The ASCII code for "A" is: H'41.
The ASCII code for "B" is: H'42.
The ASCII code for """ is: H'22.

Character String Data Blocks Reservation

Syntax

```
[<symbol>[:]] .SDATAB <block count>,"<character string>"
```

Statement Elements

1. Label

   Enter a reference symbol if required.

2. Operation

   Enter the .SDATAB mnemonic.

3. Operands

   — First operand: <block count>
   Enter the number of character strings as the first operand.

   — Second operand: <character string>
   Enter the character string to be reserved as the second operand.

Description

1. .SDATAB is the assembler directive that reserves the specified number of character strings consecutively in memory.

   Reference: Character strings → Programmer's Guide, 1.7, "Character Strings"

2. The <block count> must be specified as follows:

   — The specification must be an absolute value,
   and,
   — Forward reference symbols must not appear in the specification.

   A value of 1 or larger must be specified as the block count.

   The maximum value of the block count depends on the length of the character string data.

(The length of the character string data multiplied by the block count must be less than or equal to H'FFFFFFFF (4,294,967,295) bytes.)

3. A control character can be appended to a character string.

   The syntax for this notation is as follows:

```
"<character string>"<<ASCII code for a control character>>
```

   The ASCII code for a control character must be specified as follows:

   — The specification must be an absolute value,

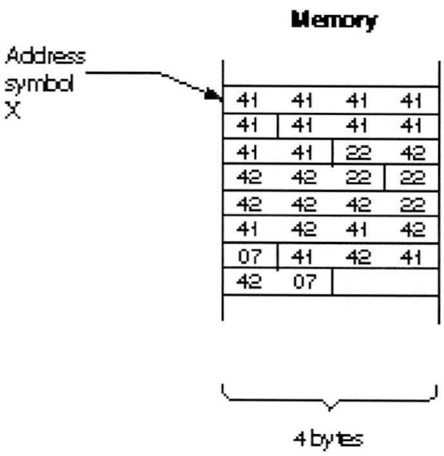
   and,

   — Forward reference symbols must not appear in the specification.

Coding Example

```
          ~
          .ALIGN    4                   ; (This statement adjusts the value of the
                                        ; location counter.)
X:        .SDATAB   2,"AAAAA"           ; This statement reserves two character string
                                        ; data blocks.
          .SDATAB   2,"""BBB"""         ; The character string in this example includes
                                        ; double quotation marks.
          .SDATAB   2,"ABAB"<H'07>      ; The character string in this example has
                                        ; a control character appended.
          ~
```

Explanatory Figure for the Coding Example



Notes: 1. The data in this figure is hexadecimal.

2. The ASCII code for "A" is: H'41.
The ASCII code for "B" is: H'42.
The ASCII code for """ is: H'22.

```
.SDATAC
```

Character String Data Reservation (With Length)

Syntax

```
[<symbol>[:]] .SDATAC "<character string>"[,"<character string>"...]
```

Statement Elements

1. Label

   Enter a reference symbol if required.

2. Operation

   Enter the .SDATAC mnemonic.

3. Operands

   Enter the character string(s) to be reserved.

Description

1. .SDATAC is the assembler directive that reserves character string data (with length) in memory.

   A character string with length is a character string with an inserted leading byte that indicates the length of the string.

   The length indicates the size of the character string (not including the length) in bytes.

   Reference: Character strings → Programmer's Guide, 1.7, "Character Strings"

2. A control character can be appended to a character string.

   The syntax for this notation is as follows:

   ```
   "<character string>"<<ASCII code for a control character>>
   ```

   The ASCII code for a control character must be specified as follows:

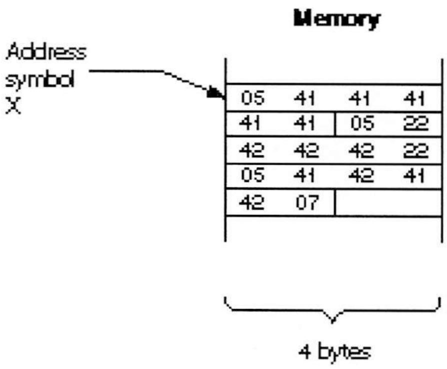
— The specification must be an absolute value,
  and,
— Forward reference symbols must not appear in the specification.

Coding Example

```
          ~

          .ALIGN      4              ; (This statement adjusts the value of the
                                     ; location counter.)
X:        .SDATAC     "AAAAA"        ; This statement reserves character string
                                     ; data (with length).
          .SDATAC     """BBB"""      ; The character string in this example includes
                                     ; double quotation marks.
          .SDATAC     "ABAB"<H'07>   ; The character string in this example has
                                     ; a control character appended.
          ~
```

Explanatory Figure for the Coding Example



Notes: 1. The data in this figure is hexadecimal.
2. The ASCII code for "A" is: H'41.
The ASCII code for "B" is: H'42.
The ASCII code for """ is: H'22.

```
.SDATAZ
```

Character String Data Reservation (With Zero Terminator)

Syntax

```
[<symbol>[:]] .SDATAZ "<character string>"[,"<character string>"...]
```

Statement Elements

1. Label

   Enter a reference symbol if required.

2. Operation

   Enter the .SDATAZ mnemonic.

3. Operands

   Enter the character string(s) to be reserved.

Description

1. .SDATAZ is the assembler directive that reserves character string data (with zero terminator) in memory.

   A character string with zero terminator is a character string with an appended trailing byte (with the value H'00) that indicates the end of the string.

   Reference: Character strings → Programmer's Guide, 1.7, "Character Strings"

2. A control character can be appended to a character string.

   The syntax for this notation is as follows:

   ```
   "<character string>"<<ASCII code for a control character>>
   ```

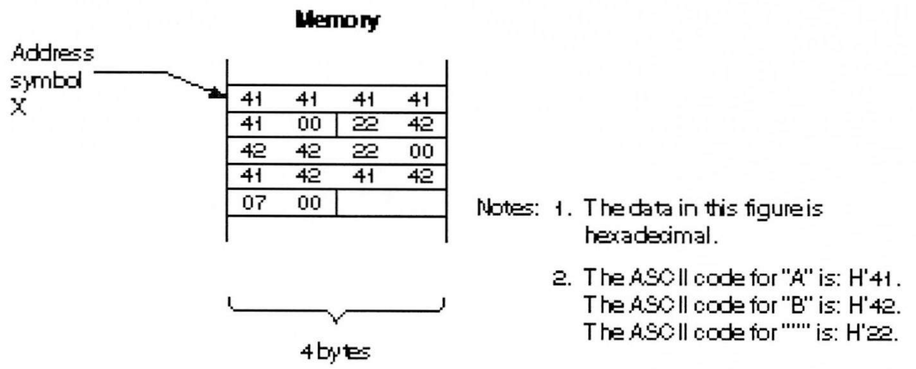
   The ASCII code for a control character must be specified as follows:

— The specification must be an absolute value,
  and,
— Forward reference symbols must not appear in the specification.

Coding Example

```
        ~
        .ALIGN     4             ; (This statement adjusts the value of the
                                 ; location counter.)
X:      .SDATAZ    "AAAAA"       ; This statement reserves character string
                                 ; data (with zero terminator).
        .SDATAZ    """BBB"""     ; The character string in this example
                                 ; includes double quotation marks.
        .SDATAZ    "ABAB"<H'07>  ; The character string in this example has
                                 ; a control character appended.
        ~
```

Explanatory Figure for the Coding Example



.FDATA

Floating-Point Data Reservation

Syntax

```
[<symbol>[:]] .FDATA[.operation size] <floating-point data>
                                     [,<floating-point data>...]
```

Statement Elements

1. Label

   Enter a reference symbol if required.

2. Operation

   — Mnemonic
   Enter .FDATA mnemonic.

   — Operation size

Specifier	Data Size
S	Single precision (4 bytes)
D	Double precision (8 bytes)

   The shaded section indicates the default value when the specifier is omitted.

   The specifier determines the size of the reserved data.
   Single precision is used when the specifier is omitted.

3. Operands

   Enter the values to be reserved as data.

Description

1. .FDATA is the assembler directive that reserves floating-point data in memory.

   Reference: Floating-point data
   → Programmer's Guide, 1.4.3, "Floating-Point Constants"

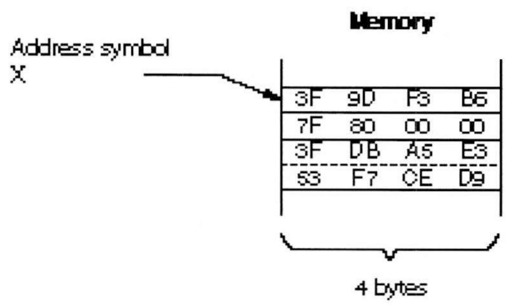
Coding Example

```
            ~

        .ALIGN      4                ; (This statement adjusts the value of the
                                     ; location counter.)

X:      .FDATA.S    F'1.234S         ; This statement reserves a 4-byte area
                                     ; 3F9DF3B6 (F'1.234S).
        .FDATA.S    H'7F800000.S     ; This statement reserves a 4-byte area
                                     ; 7F800000 (H'F800000.S).
        .FDATA.D    F'4.32D-1        ; This statement reserves an 8-byte area
                                     ; 3FDBA5E353F7CED9 (F'4.32D-1).
            ~
```

Explanatory Figure for the Coding Example



`.FDATAB`

Floating-Point Data Block Reservation

Syntax

```
[<symbol>[:]]  .FDATAB[.operation size] <block count>,
                                          <floating-point data>
```

Statement Elements

1. Label

   Enter a reference symbol if required.

2. Operation

   — Mnemonic
   Enter .FDATAB mnemonic.

   — Operation size

Specifier	Data Size
S	Single precision (4 bytes)
D	Double precision (8 bytes)

The shaded section indicates the default value when the specifier is omitted.

The specifier determines the size of the reserved data.
Single precision is used when the specifier is omitted.

3. Operands

   — First operand: block count
   Enter the number of times the data value is repeated as the first operand.

   — Second operand: floating-point data
   Enter the floating-point data to be reserved as the second operand.

Description

1. .FDATAB is the assembler directive that reserves the specified number of floating-point data items consecutively in memory.

2. The block count must be specified as follows:

   — The specification must be an absolute value,
   and,
   — Forward reference symbols, export symbols, and relative symbols must not appear in specification.

3. The range of values that can be specified as the block size varies with the operation size.

Operation Size	Block Size Range*	
S	H'00000001 to H'3FFFFFFF	(1 to 1,073,741,823)
D	H'00000001 to H'1FFFFFFF	(1 to 536,870,911)

Note: Numbers in parentheses are decimal.

Reference: Floating-point data
→ Programmer's Guide, 1.4.3, "Floating-Point Constants"

Coding Example

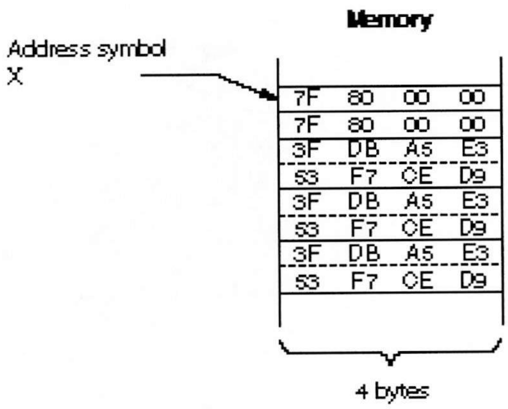
```
         ~

         .ALIGN      4                  ; (This statement adjusts the value of the
                                        ; location counter.)

X:       .FDATAB.S   2,H'7F800000.S     ; This statement reserves two blocks of 4-byte
                                        ; areas 7F800000 (H'7F800000.S).
         .FDATAB.D   3,F'4.32D-1        ; This statement reserves three blocks of 8-byte
                                        ; areas 3FDBA5E353F7CED9 (F'4.32D-1).

         ~
```

Explanatory Figure for the Coding Example



Fixed-Point Data Reservation

Syntax

```
[<symbol>[:]] .XDATA[.<operation size>] <fixed-point data>
                                         [,<fixed-point data>...]
```

Statement Elements

1. Label

   Enter a reference symbol if required.

2. Operation

   — Mnemonic
   Enter .XDATA mnemonic.

   — Operation size

Specifier	Data Size
W	Word (2 bytes)
L	Longword (4 bytes)

The shaded section indicates the default value when the specifier is omitted.

The specifier determines the size of the reserved data.
The longword size is used when the specifier is omitted.

3. Operands

   Enter the fixed-point data to be reserved as data in the operand field.

Description

1. .XDATA is the assembler directive that reserves fixed-point data in memory.

   Reference: Fixed-point data
   → Programmer's Guide, 1.4.4, "Fixed-Point Constants"

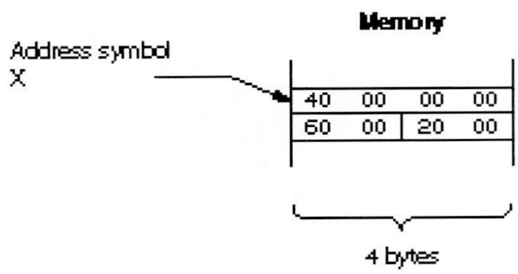
Coding Example

```
        ~

        .ALIGN      4               ; (This statement adjusts the value of the
                                    ; location counter.)

X:      .XDATA.L    0.5             ; This statement reserves 4-byte area
                                    ; (H'40000000).
        .XDATA.W    0.75,0.25       ; This statement reserves 2-byte areas
                                    ; (H'6000) and (H'2000).
        ~
```

Explanatory Figure for the Coding Example



Data Area Reservation

Syntax

```
[<symbol>[:]] .RES[.<operation size>] <area count>
```

Statement Elements

1. Label

   Enter a reference symbol if required.

2. Operation

   — Mnemonic
   Enter .RES mnemonic.

   — Operation size

Specifier	Data Size
B	Byte
W	Word (2 bytes)
L	Longword (4 bytes)

   The shaded section indicates the default value when the specifier is omitted.

   The specifier determines the size of one area.
   The longword size is used when the specifier is omitted.

3. Operands

   Enter the number of areas to be reserved in the operand field.

Description

1. .RES is the assembler directive that reserves data areas in memory.

2. The area count must be specified as follows:

   — The specification must be an absolute value,
   and,
   — Forward reference symbols must not appear in the specification.

3. The range of values that can be specified as the area count varies with the operation size.

Operation Size	Area Count Range*
B	H'00000001 to H'FFFFFFFF (1 to 4,294,967,295)
W	H'00000001 to H'7FFFFFFF (1 to 2,147,483,647)
L	H'00000001 to H'3FFFFFFF (1 to 1,073,741,823)

Note: Numbers in parentheses are decimal.

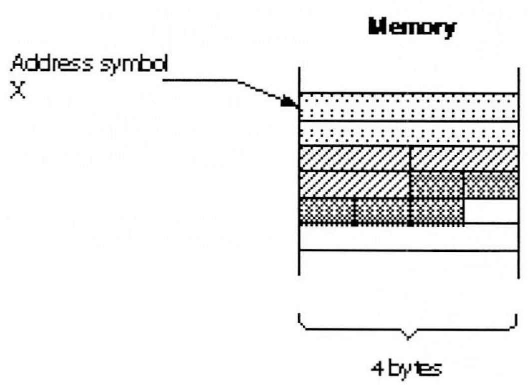
Coding Example

```
         ~

         .ALIGN     4          ; (This statement adjusts the value of the location
                               ; counter.)
X:       .RES.L     2          ; This statement reserves two longword-size areas.
         .RES.W     3          ; This statement reserves three-word-size areas.
         .RES.B     5          ; This statement reserves five-byte-size areas.

         ~
```

Explanatory Figure for the Coding Example



```
.SRES
```

Character String Data Area Reservation

Syntax

```
[<symbol>[:]] .SRES <character string area size>
                           [,<character string area size>...]
```

Statement Elements

1. Label

   Enter a reference symbol if required.

2. Operation

   Enter the .SRES mnemonic.

3. Operands

   Enter the sizes of the areas to be reserved in byte units.

Description

1. .SRES is the assembler directive that reserves character string data areas.

2. The character string area size must be specified as follows:

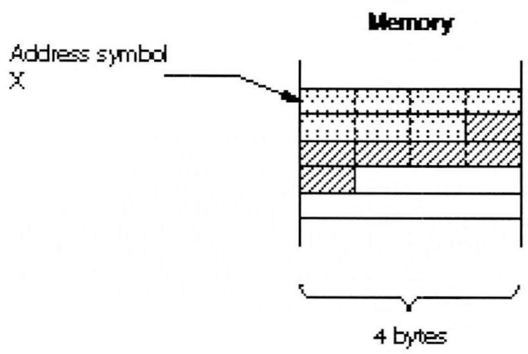
   — The specification must be an absolute value,
   and,
   — Forward reference symbols must not appear in the specification.

   The values that are allowed for the character string area size are from H'00000001 to H'FFFFFFFF (from 1 to 4,294,967,295 in decimal).

Coding Example

```
          ~
        .ALIGN     4              ; (This statement adjusts the value of the location
                                  ; counter.)
X:      .SRES      7              ; This statement reserves a 7-byte area.
        .SRES      6              ; This statement reserves a 6-byte area.
          ~
```

Explanatory Figure for the Coding Example



```
.SRESC
```

Character String Data Area Reservation (With Length)

Syntax

```
[<symbol>[:]] .SRESC <character string area size>
                        [,<character string area size>...]
```

Statement Elements

1. Label

   Enter a reference symbol if required.

2. Operation

   Enter the .SRESC mnemonic.

3. Operands

   Enter the sizes of the areas (not including the length) to be reserved in byte units.

Description

1. .SRESC is the assembler directive that reserves character string data areas (with length) in memory.

   A character string with length is a character string with an inserted leading byte that indicates the length of the string.

   The length indicates the size of the character string (not including the length) in bytes.

   Reference: Character strings → Programmer's Guide, 1.7, "Character Strings"

2. The character string area size must be specified as follows:

   — The specification must be an absolute value,

   and,

   — Forward reference symbols must not appear in the specification.

   The values that are allowed for the character string area size are from H'00000000 to H'000000FF (from 0 to 255 in decimal).

3. The size of the area reserved in memory is the size of the character string area itself plus 1 byte for the count.

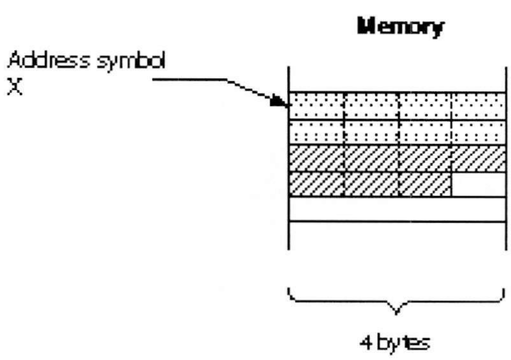
Coding Example

```
          ~

          .ALIGN    4          ; (This statement adjusts the value of the location
                               ; counter.)
X:        .SRESC    7          ; This statement reserves 7 bytes plus 1 byte for
                               ; the count.
          .SRESC    6          ; This statement reserves 6 bytes plus 1 byte for
                               ; the count.

          ~
```

Explanatory Figure for the Coding Example



.SRESZ

Character String Data Area Reservation (With Zero Terminator)

Syntax

```
[<symbol>[:]] .SRESZ <character string area size>
                          [,<character string area size>...]
```

Statement Elements

1. Label

   Enter a reference symbol if required.

2. Operation

   Enter the .SRESZ mnemonic.

3. Operands

   Enter the sizes of the areas (not including the terminating zero) to be reserved in byte units.

Description

1. .SRESZ is the assembler directive that allocates character string data areas (with zero termination).

   A character string with length is a character string with an appended trailing byte (with the value H'00) that indicates the end of the string.

   Reference: Character strings → Programmer's Guide, 1.7, "Character Strings"

2. The character string area size must be specified as follows:

   — The specification must be an absolute value,
   and,
   — Forward reference symbols must not appear in the specification.

   The values that are allowed for the character string area size are from H'00000000 to H'000000FF (from 0 to 255 in decimal).

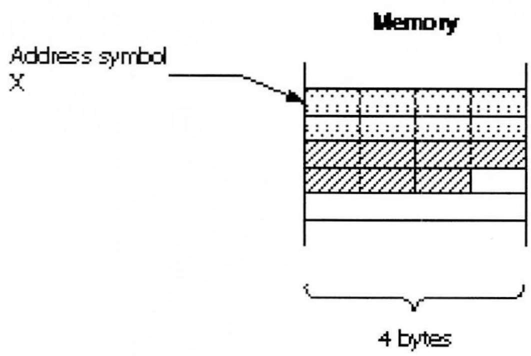
3. The size of the area reserved in memory is the size of the character string area itself plus 1 byte for the terminating zero.

Coding Example

```
        ~
        .ALIGN      4       ; (This statement adjusts the value of the location
counter.)

X:      .SRESZ      7       ; This statement reserves 7 bytes plus 1 byte for
                            ; the terminating byte.
        .SRESZ      6       ; This statement reserves 6 bytes plus 1 byte for
                            ; the terminating byte.
        ~
```

Explanatory Figure for the Coding Example



.FRES

Floating-Point Data Area Reservation

Syntax

```
[<symbol>[:]] .FRES[S] <area count>
```

Statement Elements

1. Label

   Enter a reference symbol if required.

2. Operation

   — Mnemonic
   Enter .FRES mnemonic.

   — Operation size

Specifier	Data Size
S	Single precision (4 bytes)
D	Double precision (8 bytes)

   The shaded section indicates the default value when the specifier is omitted.

   The specifier determines the size of one area.
   Single precision is used when the specifier is omitted.

3. Operands

   Enter the number of areas (the number of single-precision data items).

Description

1. .FRES is the assembler directive that reserves floating-point data areas in memory.

2. The area count must be specified as follows:

   — The specification must be an absolute value,
   and,
   — Forward reference symbols, import symbols, and relative symbols must not appear in the specification.

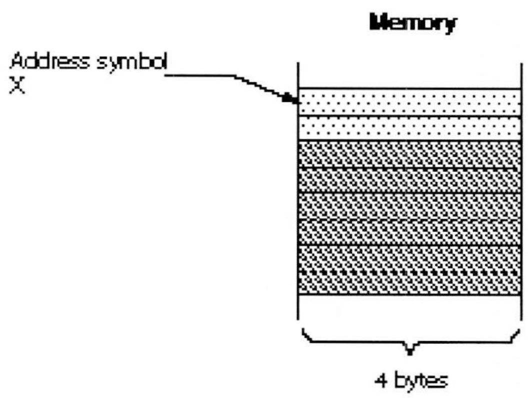
Coding Example

```
        ~

        .ALIGN    4          ; (This statement adjusts the value of the location
                             ; counter.)
X:      .FRES.S   2          ; This statement reserves two areas.
        .FRES.D   3          ; This statement reserves three areas.

        ~
```

Explanatory Figure for the Coding Example



5.2.5 Export and Import Assembler Directives

This assembler provides the following assembler directives concerned with export and import.

.EXPORT

Declares export symbols.

This declaration allows symbols defined in the current file to be referenced in other files.

.IMPORT

Declares import symbols.

This declaration allows symbols defined in other files to be referenced in the current file.

.GLOBAL

Declares export and import symbols.

This declaration allows symbols defined in the current file to be referenced in other files, and allows symbols defined in other files to be referenced in the current file.

Export Symbols Declaration

Syntax

```
.EXPORT <symbol>[,<symbol>...]
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .EXPORT mnemonic.

3. Operands

   Enter the symbols to be declared as export symbols.

Description

1. .EXPORT is the assembler directive that declares export symbols.

   An export symbol declaration is required to reference symbols defined in the current file from other files.

2. The following can be declared to be export symbols.

   — Constant symbols (other than those defined with the .ASSIGN directive)
   — Absolute address symbols (other than address symbols in a dummy section)
   — Relative address symbols

3. To reference a symbol as an import symbol, it is necessary to declare it to be an export symbol, and also to declare it to be an import symbol.

   Import symbols are declared in the file in which they are referenced using either the .IMPORT or the .GLOBAL directive.

Coding Example

(In this example, a symbol defined in file A is referenced from file B.)

File A:

```
        .EXPORT   X              ; This statement declares X to be an export
                                 ; symbol.
           ~

X:      .EQU      H'10000000     ; This statement defines X.
```

```
           ~
```

File B:

```
        .IMPORT   X              ; This statement declares X to be an import
                                 ; symbol.
           ~

        .ALIGN    4
        .DATA.L   X              ; This statement references X.

           ~
```

Import Symbols Declaration

Syntax

```
.IMPORT <symbol>[,<symbol>...]
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .IMPORT mnemonic.

3. Operands

   Enter the symbols to be declared as import symbols.

Description

1. .IMPORT is the assembler directive that declares import symbols.

   An import symbol declaration is required to reference symbols defined in another file.

2. Symbols defined in the current file cannot be declared to be import symbols.

3. To reference a symbol as an import symbol, it is necessary to declare it to be an export symbol, and also to declare it to be an import symbol.

   Export symbols are declared in the file in which they are defined using either the .EXPORT or the .GLOBAL directive.

Coding Example

(In this example, a symbol defined in file A is referenced from file B.)

File A:

```
        .EXPORT    X             ; This statement declares X to be an export
                                 ; symbol.
          ~

X:      .EQU       H'10000000    ; This statement defines X.

          ~
```

File B:

```
        .IMPORT    X             ; This statement declares X to be an import
                                 ; symbol.
          ~

        .ALIGN     4
        .DATA.L    X             ; This statement references X.

          ~
```

Export and Import Symbols Declaration

Syntax

```
.GLOBAL <symbol>[,<symbol>...]
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .GLOBAL mnemonic.

3. Operands

   Enter the symbols to be declared as export symbols or as import symbols.

Description

1. .GLOBAL is the assembler directive that declares symbols to be either export symbols or import symbols.

   An export symbol declaration is required to reference symbols defined in the current file from other files. An import symbol declaration is required to reference symbols defined in another file.

2. A symbol defined within the current file is declared to be an export symbol by a .GLOBAL declaration.

   A symbol that is not defined within the current file is declared to be an import symbol by a .GLOBAL declaration.

3. The following can be declared to be export symbols.

   — Constant symbols (other than those defined with the .ASSIGN assembler directive)
   — Absolute address symbols (other than address symbols in a dummy section)
   — Relative address symbols

4. To reference a symbol as an import symbol, it is necessary to declare it to be an export symbol, and also to declare it to be an import symbol.

   Export symbols are declared in the file in which they are defined using either the .EXPORT or the .GLOBAL directive.

   Import symbols are declared in the file in which they are referenced using either the .IMPORT or the .GLOBAL directive.

Coding Example

(In this example, a symbol defined in file A is referenced from file B.)

File A:

```
         .GLOBAL    X             ; This statement declares X to be an export
                                  ; symbol.
           ~
X:       .EQU       H'10000000    ; This statement defines X.
           ~
```

File B:

```
         .GLOBAL    X             ; This statement declares X to be an import
                                  ; symbol.
           ~
         .ALIGN     4
         .DATA.L    X             ; This statement references X.
           ~
```

5.2.6 Object Module Assembler Directives

This assembler provides the following assembler directives concerned with object modules.

`.OUTPUT`

Controls object module and debug information output.

`.DEBUG`

Controls the output of symbolic debug information.

`.ENDIAN`

Selects big endian or little endian.

`.LINE`

Changes line number.

```
.OUTPUT
```

Object Module Output Control

Syntax

```
.OUTPUT <output specifier>[,<output specifier>]
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .OUTPUT mnemonic.

3. Operands: <output specifier>

Output Specifier	Output Control
OBJ	An object module is output.
NOOBJ	No object module is output.
DBG	Debug information is output in the object module.
NODBG	No debug information is output in the object module.

   The shaded section indicates the default value when the specifier is omitted.

   The output specifiers control object module and debug information output.

Description

1. .OUTPUT is the assembler directive that controls object module and debug information output.

2. If the .OUTPUT directive is used two or more times in a program with inconsistent output specifiers, an error occurs.

   Example:

```
  ~
.OUTPUT   OBJ
.OUTPUT   NODBG
  ~
```
← OK

```
  ~
.OUTPUT   OBJ
.OUTPUT   NOOBJ
  ~
```
← Error

3. Specifications concerning debug information output are only valid when an object module is output.

4. To output debug information, the assembler automatically generates a directory with the name "dwfinf" under the directory to which the object file is output, and outputs a supplement debugging information file (ELF/DWARF supplement information) whose file name is the same as the object file and whose file format is "dwi".

5. The assembler gives priority to command line option specifications concerning object module and debug information output.

References: Object module output

→ User's Guide, 2.2.2, "Object Module Command Line Options" –OBJECT –NOOBJECT

Debug information output

→ User's Guide, 2.2.2, "Object Module Command Line Options" –DEBUG –NODEBUG

Coding Example

Note: This example and its description assume that no command line options concerning object module or debug information output were specified.

```
        .OUTPUT     OBJ              ; An object module is output.
                                     ; No debug information is output.
           ~
-----------------------------------------------------------------------
        .OUTPUT     OBJ,DBG          ; Both an object module and debug information
                                     ; is output.
           ~
-----------------------------------------------------------------------
        .OUTPUT     OBJ,NODBG        ; An object module is output.
                                     ; No debug information is output.
           ~
```

Supplement:

Debug information is required when debugging a program using the debugger, and is part of the object module.

Debug information includes information about source statements and information about symbols.

Symbolic Debug Information Output Control

Syntax

```
.DEBUG <output specifier>
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .DEBUG mnemonic.

3. Operands: output specifier

Output Specifier	Output Control
ON	Symbolic debug information is output starting with the next source statement.
OFF	Symbolic debug information is not output starting with the next source statement.

The shaded section indicates the default value when the specifier is omitted.

The output specifier controls symbolic debug information output.

Description

1. .DEBUG is the assembler directive that controls the output of symbolic debug information.

   This directive allows assembly time to be reduced by restricting the output of symbolic debug information to only those symbols required in debugging.

2. The specification of the .DEBUG directive is only valid when both an object module and debug information are output.

References: Object module output

→ Programmer's Guide, 5.2.6, "Object Module Assembler Directives", .OUTPUT

→ User's Guide, 2.2.2 "Object Module Command Line Options" –OBJECT –NOOBJECT

Debug information output

→ Programmer's Guide 5.2.6, "Object Module Assembler Directives", .OUTPUT

→ User's Guide, 2.2.2, "Object Module Command Line Options" –DEBUG –NODEBUG

Coding Example

```
        ~

    .DEBUG      OFF         ; Starting with the next statement, the assembler
                            ; does not output symbolic debug information.
        ~

    .DEBUG      ON          ; Starting with the next statement, the assembler
                            ; outputs symbolic debug information.
        ~
```

Supplement:

The term "symbolic debug information" refers to the parts of debug information concerned with symbols.

Endian Selection

Syntax

```
 .ENDIAN <endian>

<endian>:{BIG|LITTLE}
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .ENDIAN mnemonic.

3. Operands: endian

Endian	Output Control
BIG	Assembles program in big endian
LITTLE	Assembles program in little endian

The shaded section indicates the default value when the specifier is omitted.

Description

1. .ENDIAN is the assembler directive that selects the big endian or little endian.

2. Enter an .ENDIAN directive at the beginning of the source program.

3. If the –ENDIAN option has been specified, the .ENDIAN is invalidated.

   Reference: –ENDIAN
   → User's Guide, 2.2.2 "Object Module Command Line Options" –ENDIAN

Coding Example

1. When the big endian is selected

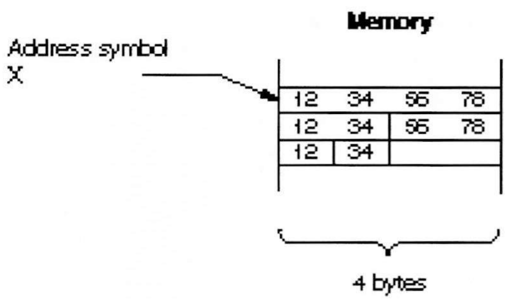
```
         .CPU        SH1            ; This statement specifies the SH1 as the CPU.
         .ENDIAN     BIG            ; This statement selects the big endian.

             ~

X:       .DATA.L     H'12345678     ;
X:       .DATA.W     H'1234,H'5678  ; These statements reserve integer data.
X:       .DATA.B     H'12,H'34      ;

             ~
```

Explanatory Figure for the Coding Example



Note: The data in this figure is hexadecimal.

2. When the little endian is selected

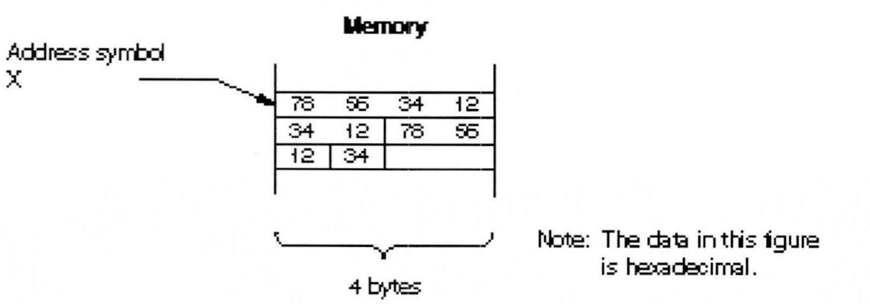
```
          .CPU        SH3             ; This statement specifies the SH3 as the CPU.
          .ENDIAN     LITTLE          ; This statement selects the little endian.

            ~

X:        .DATA.L     H'12345678      ;
X:        .DATA.W     H'1234,H'5678   ; These statements reserve integer data.
X:        .DATA.B     H'12,H'34       ;

            ~
```

Explanatory Figure for the Coding Example



`.LINE`

Line Number Modification

Syntax

```
.LINE ["<file name>",]<line number>
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .LINE mnemonic.

3. Operands

   — First operand: file name
   Enter the file name referred to at error message output or at debugging.

   — Second operand: line number
   Enter the line number referred to at error message output or at debugging.

Description

1. .LINE is the assembler directive that changes the file name and line number referred to at error message output or at debugging.

2. The line number and the file name specified with a .LINE directive is valid until the next .LINE.

3. In a C Compiler of version 3.0 or higher, the .LINE directive that corresponds to the line number in the C source file is generated when the debug option is specified and an assembler source is output.

4. If the file name is omitted, the file name is not changed, but only the line number is changed.

Coding Example

```
shc  -code=asmcode -debug test.c
```

C source program (test.c)

```
int    func()
{
    int   i,j;

    j=0;
    for (i=1;i<=10;i++){
        j+=i;
    }
    return(j);
}
```

→

Assembly source program (test.src)

```
          .EXPORT    _func
          .SECTION   P,CODE,ALIGN=4
          .LINE      "/asm/test.c",1
_func:                      ; function: func
                            ; frame size=0
          .LINE      "/asm/test.c",5
          MOV        #0,R5
          .LINE      "/asm/test.c",6
          MOV        #10,R6
          MOV        #1,R4
L212:
          .LINE      "/asm/test.c",7
          ADD        R4,R5
          ADD        #1,R4
          .LINE      "/asm/test.c",6
          CMP/GT     R6,R4
          BF         L212
          .LINE      "/asm/test.c",10
          RTS
          .LINE      "/asm/test.c",9
          MOV        R5,R0
          .END
```

5.2.7 Assemble Listing Assembler Directives

This assembler provides the following assembler directives for controlling the assemble listing.

`.PRINT`	Controls assemble listing output.
`.LIST`	Controls the output of the source program listing.
`.FORM`	Sets the number of lines and columns in the assemble listing.
`.HEADING`	Sets the header for the source program listing.
`.PAGE`	Inserts a new page in the source program listing.
`.SPACE`	Outputs blank lines to the source program listing.

Supplement:

The assemble listing is a listing to which the results of the assembly are output, and includes a source program listing, a cross-reference listing, and a section information listing.

Reference: For a detailed description of the assemble listing, see appendix C, "Assemble Listing Output Example".

Assemble Listing Output Control

Syntax

```
.PRINT <output specifier>[,<output specifier>...]
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .PRINT mnemonic.

3. Operands: output specifier

Output Specifier	Assembler Action
LIST	An assemble listing is output.
NOLIST	No assemble listing is output.
SRC	A source program listing is output in the assemble listing.
NOSRC	No source program listing is output in the assemble listing.
CREF	A cross-reference listing is output in the assemble listing.
NOCREF	No cross-reference listing is output in the assemble listing.
SCT	A section information listing is output in the assemble listing.
NOSCT	No section information listing is output in the assemble listing.

The shaded sections indicate the default settings when the specifier is omitted.

The output specifier controls assemble listing output.

Description

1. .PRINT is the assembler directive that controls assemble listing output.

2. If the .PRINT directive is used two or more times in a program with inconsistent output specifiers, an error occurs.

   Example:

```
     ~
.PRINT   LIST
.PRINT   NOSRC       ← OK
     ~
```

```
     ~
.PRINT   LIST
.PRINT   NOLIST      ← Error
     ~
```

3. The output specifiers concerned with the source program listing, the cross-reference listing, and the section information listing are only valid when an assemble listing is output.

4. The assembler gives priority to command line option specifications concerning assemble listing output.

   References: Assemble listing output
   → User's Guide, 2.2.3, "Assemble Listing Command Line Options"
   –LIST –NOLIST
   –SOURCE –NOSOURCE
   –CROSS_REFERENCE –NOCROSS_REFERENCE
   –SECTION –NOSECTION

Coding Example

Note: This example and its description assume that no command line options concerning assemble listing output are specified.

```
        .PRINT    LIST                    ; All types of assemble listing are output.

          ~
-----------------------------------------------------------------------
        .PRINT    LIST,NOSRC,NOCREF
                                          ; Only a section information listing is output.
          ~
```

Source Program Listing Output Control

Syntax

```
.LIST <output specifier>[,<output specifier>...]

Output specifier: {ON|OFF|COND|NOCOND|DEF|NODEF|CALL|NOCALL|
                   EXP|NOEXP|CODE|NOCODE}
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .LIST mnemonic.

3. Operands

   Enter the output specifiers.

Description

1. .LIST is the assembler directive that controls output of the source program listing in the following three ways:

   a Selects whether or not to output source statements.

   b Selects whether or not to output source statements related to the conditional assembly and macro functions.

   c Selects whether or not to output object code lines.

2. Output is controlled by output specifiers as follows:

Type	Output Specifier: Output	Output Specifier: Not output	Object	Description
a	ON	OFF	Source statements	The source statements following this directive
b	COND	NOCOND	Failed condition	Condition-failed .AIF or .AIFDEF directive statements
	DEF	NODEF	Definition	Macro definition statements .AREPEAT and .AWHILE definition statements .INCLUDE directive statements .ASSIGNA and .ASSSIGNC directive statements
	CALL	NOCALL	Call	Macro call statements, .AIF, AIFDEF, and .AENDI directive statements
	EXP	NOEXP	Expansion	Macro expansion statements .AREPEAT and .AWHILE expansion statements
c	CODE	NOCODE	Object code lines	The object code lines exceeding the source statement lines

The shaded sections indicate the default settings when the specifier is omitted.

3. The specification of the .LIST directive is only valid when an assemble listing is output.

   References: Source program listing output
   → Programmer's Guide, 5.2.7, "Assemble Listing Assembler Directives", .PRINT
   → User's Guide, 2.2.3, "Assemble Listing Command Line Options", –LIST –NOLIST –SOURCE –NOSOURCE

4. The assembler gives priority to command line option specifications concerning source program listing output.

   Reference: Output on the source program listing
   → User's Guide, 2.2.3, "Assemble Listing Command Line Options" –SHOW –NOSHOW

5. .LIST directive statements themselves are not output on the source program listing.

Coding Example

```
        .LIST    NOCOND,NODEF          -------- This statement controls source program
        .MACRO   SHLRN    COUNT,Rd     ----┐    listing output.
                                           |
SHIFT   .ASSIGNA \COUNT                    |
                                           |
        .AIF \&SHIFT GE 16                 |
         SHLR16   \Rd                      |
SHIFT   .ASSIGNA \&SHIFT-16                |
        .AENDI                             |
                                           |
        .AIF \&SHIFT GE 8                  |
         SHLR8    \Rd                      |
SHIFT   .ASSIGNA \&SHIFT-8                 |
        .AENDI                             |
                                           |   These statements define a general-
        .AIF \&SHIFT GE 4                  |   purpose multiple-bit shift procedure as a
         SHLR2    \Rd                      |   macro instruction.
         SHLR2    \Rd                      |
SHIFT   .ASSIGNA \&SHIFT-4                 |
        .AENDI                             |
                                           |
        .AIF \&SHIFT GE 2                  |
         SHLR2    \Rd                      |
SHIFT   .ASSIGNA \&SHIFT-2                 |
        .AENDI                             |
                                           |
        .AIF \&SHIFT GE 1                  |
         SHLR     \Rd                      |
        .AENDI                             |
        .ENDM                          ----┘

        SHLRN     23,R0                -------- Macro call
```

Source Listing Output of Coding Example

The .LIST directive suppresses the output of the macro definition, .ASSIGNA and .ASSIGNC directive statements, and .AIF and .AIFDEF condition-failed statements.

```
31                            31
32                            32            SHLRN     23,R0
33                               M
35                               M
36                               M          .AIF 23   GE 16
37 00000000 4029                 C           SHLR16   R0
39                               M          .AENDI
40                               M
41                               M          .AIF 7    GE 8
45                               M
46                               M          .AIF 7    GE 4
47 00000002 4009                 C           SHLR2    R0
48 00000004 4009                 C           SHLR2    R0
50                               M          .AENDI
51                               M
52                               M          .AIF 3    GE 2
53 00000006 4009                 C           SHLR2    R0
55                               M          .AENDI
56                               M
57                               M          .AIF 1    GE 1
58 00000008 4001                 C           SHLR     R0
59                               M          .AENDI
```

Assemble Listing Line Count and Column Count Setting

Syntax

```
.FORM <size specifier>[,<size specifier>...]
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .FORM mnemonic.

3. Operands: size specifier

Size Specifier	Listing Size
LIN=<line count>	The specified value is set to the number of lines per page.
COL=<column count>	The specified value is set to the number of columns per line.

   These specifications determine the number of lines and columns in the assemble listing.

Description

1. .FORM is the assembler directive that sets the number of lines per page and columns per line in the assemble listing.

2. The line count and column count must be specified as follows:

   — The specifications must be absolute values,
   and,
   — Forward reference symbols must not appear in the specifications.

   The values allowed for the line count are from 20 to 255.

   The values allowed for the column count are from 79 to 255.

3. The .FORM directive can be used any number of times in a given source program.

4. The assembler gives priority to command line option specifications concerning the number of lines and columns in the assemble listing.

   References: Setting the line count in assemble listing
   → User's Guide, 2.2.3, "Assemble Listing Command Line Options" –LINES

   Setting the column count in assemble listing
   → User's Guide, 2.2.3, "Assemble Listing Command Line Options" –COLUMNS

5. When there is no specification of command line option or .FORM assembler directive specification for the line count or the column count, the following values are used:

   — Line count............ 60 lines
   — Column count........ 132 columns

Coding Example

Note: This example and its description assume that no command line options concerning the assemble listing line count and/or column count are specified.

```
        ~

    .FORM    LIN=60, COL=200    ; Starting with this page, the number of lines
                                ; per page in the assemble listing is 60 lines.
                                ; Also, starting with this line, the number of
                                ; columns per line in the assemble listing is
                                ; 200 columns.
        ~

    .FORM    LIN=55, COL=150    ; Starting with this page, the number of lines
                                ; per page in the assemble listing is 55 lines.
                                ; Also, starting with this line, the number of
                                ; columns per line in the assemble listing is
                                ; 150 columns.
        ~
```

Source Program Listing Header Setting

Syntax

```
.HEADING "<character string>"
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .HEADING mnemonic.

3. Operands: character string

   Enter the header for the source program listing.

Description

1. .HEADING is the assembler directive that sets the header for the source program listing.

   A character string of up to 60 characters can be specified as the header.

   Reference: Character strings
   → Programmer's Guide, 1.7, "Character Strings"

2. The .HEADING directive can be used any number of times in a given source program.

   The range of validity for a given use of the .HEADING directive is as follows:

   — When the .HEADING directive is on the first line of a page, it is valid starting with that page.
   — When the .HEADING directive appears on the second or later line of a page, it is valid starting with the next page.

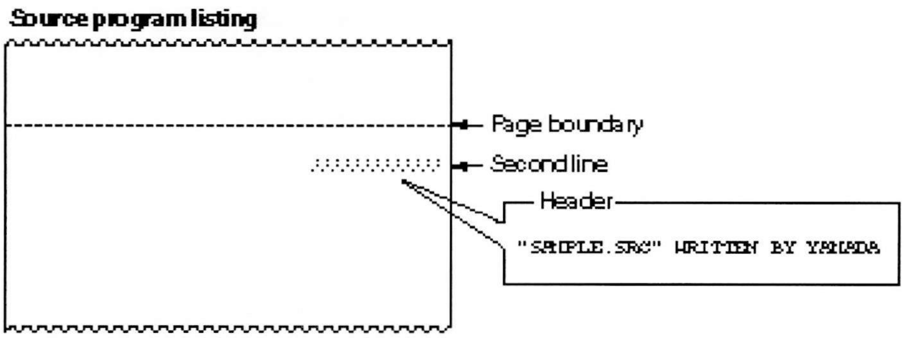
Coding Example

```
        ~

.HEADING    """SAMPLE.SRC""  WRITTEN BY YAMADA"

        ~
```

Explanatory Figure for the Coding Example



Source Program Listing New Page Insertion

Syntax

```
.PAGE
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .PAGE mnemonic.

3. Operands

   The operand field is not used.

Description

1. .PAGE is the assembler directive that inserts a new page in the source program listing at an arbitrary point.

2. The .PAGE directive is ignored if it is used on the first line of a page.

3. .PAGE directive statements themselves are not output to the source program listing.

.PAGE

Coding Example

```
~

MOV        R0,R1
RTS
MOV        R0,R2
.PAGE               ; A new page is specified here since the section changes at this point.
.SECTION   DT,DATA,ALIGN=4
.DATA.L    H'11111111
.DATA.L    H'22222222
.DATA.L    H'33333333

~
```

Explanatory Figure for the Coding Example

Source program listing

```
18  00000022  6103         18        MOV        R0,R1
19  00000024  000B         19        RTS
20  00000026  6203         20        MOV        R0,R2

------------------------------------------------------------------------  ← New page

*** SuperH RISC engine ASSEMBLER Ver. 4.0 ***       01/12/96 10:23:30
PROGRAM NAME =

22  00000000               22        .SECTION   DT,DATA,ALIGN
23  00000000  11111111     23        .DATA.L    H'11111111
24  00000004  22222222     24        .DATA.L    H'22222222
25  00000008  33333333     25        .DATA.L    H'33333333
```

Note: See appendix C, "Assemble Listing Output Example", for an explanation of the contents of the source program listing.

Source Program Listing Blank Line Output

Syntax

```
.SPACE[ <line count>]
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .SPACE mnemonic.

3. Operands: line count

   Enter the number of blank lines.

   A single blank line is output if this operand is omitted.

Description

1. .SPACE is the assembler directive that outputs the specified number of blank lines to the source program listing. Nothing is output for the lines output by the .SPACE directive; in particular line numbers are not output for these lines.

2. The line count must be specified as follows:

   — The specification must be an absolute value,
     and,
   — Forward reference symbols must not appear in the specification.

   Values from 1 to 50 can be specified as the line count.

3. When a new page occurs as the result of blank lines output by the .SPACE directive, any remaining blank lines are not output on the new page.

4. .SPACE directive statements themselves are not output to the source program listing.

Coding Example

```
        .SECTION    DT1,DATA,ALIGN=4
        .DATA.L     H'11111111
        .DATA.L     H'22222222
        .DATA.L     H'33333333
        .DATA.L     H'44444444          ; Inserts five blank lines at the point
        .SPACE  5                       ; where the section changes.
        .SECTION    DT2,DATA,ALIGN=4

           ~
```

Explanatory Figure for the Coding Example

Source program listing

```
*** SuperH RISC engine ASSEMBLER Ver. 4.0 ***        01/12/96 10:25:30
PROGRAM NAME =

     1  00000000                      1           .SECTION    DT1,DATA,ALIGN=4
     2  00000000  11111111            2           .DATA.L     H'11111111
     3  00000004  22222222            3           .DATA.L     H'22222222
     4  00000008  33333333            4           .DATA.L     H'33333333
     5  0000000C  44444444            5           .DATA.L     H'44444444





     7  00000000                      7           .SECTION    DT2,DATA,ALIGN=4

           ~
```

Note: See appendix C, "Assemble Listing Output Example", for an explanation of the contents of the source program listing.

5.2.8 Other Assembler Directives

This assembler provides the following additional assembler directives.

```
.PROGRAM
```

Sets the name of the object module.

```
.RADIX
```

Sets the radix in which integer constants with no radix specifier are interpreted.

```
.END
```

Declares the end of the source program.

```
.PROGRAM
```

Object Module Name Setting

Syntax

```
.PROGRAM <object module name>
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .PROGRAM mnemonic.

3. Operands: <object module name>

   Enter a name that identifies the object module.

Description

1. .PROGRAM is the assembler directive that sets the object module name.

   The object module name is a name that is required by the H Series Linkage Editor or the H Series Librarian to identify the object module.

2. Object module naming conventions are the same as symbol naming conventions.

   The assembler distinguishes upper-case and lower-case letter in object module names.

   Reference: Coding of symbols
   → Programmer's Guide, 1.3.2, "Coding of Symbols"

3. Setting the object module name with the .PROGRAM directive is valid only once in a given program. (The assembler ignores the second and later specifications of the .PROGRAM directive.)

4. If there is no .PROGRAM specification of the object module name, the assembler will set a default (implicit) object module name.

   The default object module name is the file name of the object file (the object module output destination).

```
Example:   Object file name ........... PROG    obj
                                         ||      ||
                                     File name  File format
                                         ↓
           Object module name ..... PROG
```

   Reference: User's Guide, 1.2, "File Specification Format"

5. The object module name can be the same as a symbol used in the program.

Coding Example

```
        .PROGRAM    PROG1        ; This statement sets the object module name to be
                                 ; PROG1.
          ~
```

.RADIX

Default Integer Constant Radix Setting

Syntax

```
.RADIX <radix specifier>
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .RADIX mnemonic.

3. Operands: radix specifier

Radix Specifier	Radix of Integer Constants with No Radix Specification
B	Binary
Q	Octal
D	Decimal
H	Hexadecimal

The shaded section indicates the default setting when the specifier is omitted.

   This specifier sets the radix (base) for integer constants with no radix specification.

Description

1. .RADIX is the assembler directive that sets the radix (base) for integer constants with no radix specification.

2. When there is no radix specification with the .RADIX directive in a program, integer constants with no radix specification are interpreted as decimal constants.

3. If hexadecimal (radix specifier H) is specified as the radix for integer constants with no radix specification, integer constants whose first digit is A through F must be prefixed with a 0 (zero). (The assembler interprets expressions that begin with A through F to be symbols.)

4. Specifications with the .RADIX directive are valid from the point of specification forward in the program.

Coding Example

```
          ~
          .RADIX    D
X:        .EQU      100          ; This 100 is decimal.
          ~
          .RADIX    H
Y:        .EQU      64           ; This 64 is hexadecimal.
          ~
```

```
          ~
          .RADIX    H
Z:        .EQU      0F           ; A zero is prefixed to this constant "0F" since it would
                                 ; be interpreted as a symbol if it were written as simply
                                 ; "F".
          ~
```

.END

Source Program End Declaration

Syntax

```
.END[ <start address>]
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .END mnemonic.

3. Operands: start address

   Enter the start address for simulation if required.

Description

1. .END is the assembler directive that declares the end of the source program.

   Assembly processing terminates at the point that the .END directive appears.

2. If a start address is specified with the .END directive in the operand field, the simulator/debugger starts simulation from that address.

3. The start address must be specified with either an absolute value or an address value.

4. The value of the start address must be an address in a code section.

Coding Example

```
          .EXPORT     START
          .SECTION    CD,CODE,ALIGN=4
START:
             ~

          .END        START             ; This statement declares the end of the source
                                        ; program.

 ; The simulator/debugger starts simulation from the address indicated by the value of the
 ; symbol START.
```

Section 6 File Inclusion Function

The file inclusion function allows source files to be inserted into other source files at assembly time. The file inserted into another file is called an included file.

This assembler provides the .INCLUDE directive to perform file inclusion. The file specified with the .INCLUDE directive is inserted at the location of the .INCLUDE directive.

Example:

Source program

```
 .INCLUDE    "FILE.H"


 .SECTION CD1,CODE,ALIGN=4
MOV #ON,R0


   ~
```

Included file FILE.H

```
ON:     .EQU   1
OFF:    .EQU   0
```

File included result (source list)

```
        .INCLUDE    "FILE.H"
ON:     .EQU   1
OFF:    .EQU   0

        .SECTION CD1,CODE,ALIGN=4
        MOV #ON,R0


         ~
```

.INCLUDE

File Inclusion

Syntax

```
.INCLUDE "<file name>"
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .INCLUDE mnemonic.

3. Operands

   Enter the file to be included.

Description

1. .INCLUDE is the file inclusion assembler directive.

2. If no file format is specified, only the file name is used as specified (the assembler does not assume any default file format).

   Reference: User's Guide, 1.2, "File Specification Format"

3. The file name can include the directory. The directory can be specified either by the absolute path (path from the route directory) or by the relative path (path from the current directory).

   Note: The current directory for the .INCLUDE directive in a source file is the directory where the assembler is initiated. The current directory for the .INCLUDE directive in an included file is the directory where the included file exits.

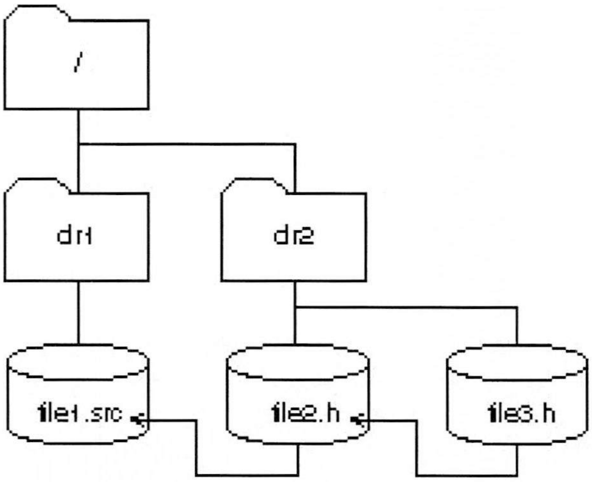
4. Included files can include other files. The nesting depth for file inclusion is limited to 30 levels (multiplex state).

5. The directory name specified by .INCLUDE can be changed by –INCLUDE.

   Reference: –INCLUDE
   → User's Guide, 2.2.4, "File Inclusion Function Command Line Option"

Coding Example

This example assumes the following directory configuration and operations:



- Starts the assembler from the route directory (/)
- Inputs source file /dir1/file1.src
- Inserts file2.h in file1.src
- Inserts file3.h in file2.h

The start command is as follows:

```
%asmsh /dir1/file1.src (RET)
```

file1.src must have the following inclusion directive:

```
    .INCLUDE "dir2/file2.h"    ; / is the current directory (relative path
specification).
or
    .INCLUDE "/dir2/file2.h"   ; Absolute path specification
```

file2.h must have the following inclusion directive:

```
    .INCLUDE "file3.h"         ; /dir2 is the current directory (relative path
                                 specification).
or
    .INCLUDE "/dir2/file3.h"   ; Absolute path specification
```

```
.INCLUDE
```

CAUTION!

When using Windows®95 or Windows®NT, change the slash (/) in the above example as follows depending on the environment.

- Japanese environment: Yen mark (¥)
- English environment: Backslash (\)

Section 7 Conditional Assembly Function

7.1 Overview of the Conditional Assembly Function

The conditional assembly function provides the following assembly operations:

- Replaces a character string in the source program with another character string.
- Selects whether or not to assemble a specified part of a source program according to the specified condition.
- Iteratively assembles a specified part of a source program.

7.1.1 Preprocessor variables

Preprocessor variables are used to write assembly conditions. Preprocessor variables are of either integer or character type.

1. Integer preprocessor variables

   Integer preprocessor variables are defined by the .ASSIGNA directive (these variables can be redefined).

   When referencing integer preprocessor variables, insert a backslash (\)* and an ampersand (&) in front of them.

Example:

```
FLAG:  .ASSIGNA 1
       ~
       .AIF \&FLAG EQ 1          ; MOV R0,R1 is assembled
        MOV R0,R1                ; when FLAG is 1.
       .AENDI
        ~
```

Note: When using a Japanese environment, use ¥ instead of \.

2. Character preprocessor variables

   Character preprocessor variables are defined by the .ASSIGNC directive (these variables can be redefined).

   When referencing character preprocessor variables, insert a backslash (\)* and an ampersand (&) in front of them.

Example:

```
FLAG:  .ASSIGNC "ON"
        ~
       .AIF "\&FLAG" EQ "ON"   ; MOV R0,R1 is assembled
        MOV R0,R1              ; when FLAG is "ON".
       .AENDI
        ~
```

Note: When using a Japanese environment, use ¥ instead of \.

7.1.2 Replacement Symbols

The .DEFINE directive specifies symbols that will be replaced with the corresponding character strings at assembly. A coding example is shown below.

Example:

```
SYM1:  .DEFINE    "R1"
        ~
       MOV.L         SYM1,R0 ; Replaced with MOV.L R1,R0.
        ~
```

7.1.3 Conditional Assembly

The conditional assembly function determines whether or not to assemble a specified part of a source program according to the specified conditions. Conditional assembly is classified into two types: conditional assembly with comparison using relational operators and conditional assembly with definition of replacement symbols.

Conditional Assembly with Comparison:

Selects the part of program to be assembled according to whether or not the specified condition is satisfied. A coding example is as follows:

```
    ~~
.AIF   <comparison condition 1>
  <Statements to be assembled when condition 1 is satisfied>
.AELIF   <comparison condition 2>
  <Statements to be assembled when condition 2 is satisfied>
.AELSE
  <Statements to be assembled when both conditions are not satisfied>
.AENDI
    ~~                           ---This part can be omitted.
```

Example:

```
   ~~
.AIF   "\&FLAG" EQ "ON"
 MOV   R0,R10            ; Assembled when FLAG
 MOV   R1,R11            ; is ON.
 MOV   R2,R12            ;
.AELSE
 MOV   R10,R0            ; Assembled when FLAG
 MOV   R11,R1            ; is not ON.
 MOV   R12,R2            ;
.AENDI
   ~~
```

Conditional Assembly with Definition:

Selects the part of program to be assembled by whether or not the specified replacement symbol has been defined. A coding example is as follows:

```
   ~~
 .AIFDEF  <definition condition>
   <Statements to be assembled when the specified replacement symbol is defined>
 .AELSE
   <Statements to be assembled when the specified replacement symbol is not defined>
 .AENDI
   ~~
                                    --This part can be omitted.
```

Example:

```
   ~~
 .AIFDEF   FLAG
  MOV      R0,R10        ; Assembled when FLAG is defined with
  MOV      R1,R11        ; the .DEFINE directive before the .AIFDEF
  MOV      R2,R12        ; directive in the program.
 .AELSE
  MOV      R10,R0        ; Assembled when FLAG is not defined with
  MOV      R11,R1        ; the .DEFINE directive before the .AIFDEF
  MOV      R12,R2        ; directive in the program.
 .AENDI
   ~~
```

7.1.4 Iterated Expansion

A part of a source program can be iteratively assembled the specified number of times. A coding example is shown below.

```
~
.AREPEAT <count>
   <Statements to be iterated>
.AENDR
~
```

Example:

```
                          ; This example is a division of 64-bit data by 32-bit data.
                          ; R1:R2 (64 bits) ÷ R0 (32 bits) = R2 (32 bits): Unsigned
TST        R0,R0          ; Zero divisor check
BT         zero_div
CMP/HS     R0,R1          ; Overflow check
BT         over_div
DIV0U                     ; Flag initialization
.AREPEAT   32
 ROTCL     R2             ; These statements are iteratively assembled 32 times.
 DIV1      R0,R1          ;
.AENDR
ROTCL      R2             ; R2 = quotient
```

7.1.5 Conditional Iterated Expansion

A part of a source program can be iteratively assembled while the specified condition is satisfied. A coding example is shown below.

```
~
.AWHILE <condition>
   <Statements to be iterated>
.AENDW
~
```

Example:

```
                                   ; This example is a multiply and accumulate
                                   ; operation.
TblSiz: .ASSIGNA  50               ; TblSiz: Data table size
        MOV       A_Tbl1,R1        ; R1: Start address of data table 1
        MOV       A_Tbl2,R2        ; R2: Start address of data table 2
        CLRMAC                     ; MAC register initialization
        .AWHILE   \&TblSiz GT 0    ; While TblSiz is larger than 0,
         MAC.W    @R0+,@R1+        ; this statement is iteratively assembled.
TblSiz: .ASSIGNA  \&TblSiz-1       ; 1 is subtracted from TblSiz.
        .AENDW
        STS       MACL,R0          ; The result is obtained in R0.
```

7.2 Conditional Assembly Directives

This assembler provides the following conditional assembly directives.

`.ASSIGNA`	Defines an integer preprocessor variable. The defined variable can be redefined.
`.ASSIGNC`	Defines a character preprocessor variable. The defined variable can be redefined.
`.DEFINE`	Defines a preprocessor replacement character string.

`.AIF`
`.AELIF`
`.AELSE`
`.AENDI`
	Determines whether or not to assemble a part of a source program according to the specified condition. When the condition is satisfied, the statements after the .AIF are assembled. When not satisfied, the statements after the .AELIF or .AELSE are assembled.

`.AIFDEF`
`.AELSE`
`.AENDI`
	Determines whether or not to assemble a part of a source program according to the replacement symbol definition. When the replacement symbol is defined, the statements after the .AIFDEF are assembled. When not defined, the statements after the .AELSE are assembled.

`.AREPEAT` `.AENDR`	Repeats assembly of a part of a source program (between .AREPEAT and .AENDR) the specified number of times.
`.AWHILE` `.AENDW`	Assembles a part of a source program (between .AWHILE and .AENDW) iteratively while the specified condition is satisfied.
`.AERROR`	Processes an error during preprocessor expansion.
`.EXITM`	Terminates .AREPEAT or .AWHILE iterated expansion.
`.ALIMIT`	Specifies the maximum count of .AWHILE expansion.

.ASSIGNA

Integer Preprocessor Variable Definition (Redefinition Is Possible)

Syntax

```
<preprocessor variable>[:] .ASSIGNA <value>
```

Statement Elements

1. Label

   Enter the name of the preprocessor variable.

2. Operation

   Enter the .ASSIGNA mnemonic.

3. Operands

   Enter the value to be assigned to the preprocessor variable.

Description

1. .ASSIGNA is the assembler directive that defines a value for an integer preprocessor variable. The syntax of integer preprocessor variables is the same as that for symbols. An integer preprocessor variable can be defined with up to 32 characters, and uppercase and lowercase letters are distinguished.

2. The preprocessor variables defined with the .ASSIGNA directive can be redefined with the .ASSIGNA directive.

3. The values for the preprocessor variables must be the following:

   — Constant (integer constant and character constant)
   — Defined preprocessor variable
   — Expression using the above as terms

4. Defined preprocessor variables are valid from the point of specification forward in the source program.

5. Defined preprocessor variables can be referenced in the following locations:

   — .ASSIGNA directive
   — .ASSIGNC directive
   — .AIF directive
   — .AELIF directive
   — .AREPEAT directive
   — .AWHILE directive
   — Macro body (source statements between .MACRO and .ENDM)

   When referencing integer preprocessor variables, insert a backslash (\)* and an ampersand (&) in front of them.

   ```
   \&<preprocessor variable>[']
   ```

   To clearly distinguish the preprocessor variable name from the rest of the source statement, an apostrophe (') can be added.

   Note: When using a Japanese environment, use ¥ instead of \.

6. When a preprocessor character string is defined by a command line option, the .ASSIGNA directive specifying the preprocessor variable having the same name as the character string is invalidated.

Coding Example

```
                                   ; This example generates a general-purpose multiple-bit
                                   ; shift instruction which shifts bits to the right by the
                                   ; number of SHIFT.
RN:     .REG        (R0)           ; R0 is set to Rn.
SHIFT:  .ASSIGNA    27             ; 27 is set to SHIFT.

        .AIF \&SHIFT GE 16         ; Condition: SHIFT  16
         SHLR16  Rn                ; When the condition is satisfied, Rn is shifted to the right by 16 bits.
SHIFT:  .ASSIGNA    \&SHIFT-16     ; 16 is subtracted from SHIFT.
        .AENDI

        .AIF \&SHIFT GE 8          ; Condition: SHIFT  8
         SHLR8   Rn                ; When the condition is satisfied, Rn is shifted to the right by 8 bits.
SHIFT:  .ASSIGNA    \&SHIFT-8      ; 8 is subtracted from SHIFT.
        .AENDI

        .AIF \&SHIFT GE 4          ; Condition: SHIFT  4
         SHLR2   Rn                ; When the condition is satisfied, Rn is shifted to the right by 4 bits.
         SHLR2   Rn                ;
SHIFT:  .ASSIGNA    \&SHIFT-4      ; 4 is subtracted from SHIFT.
        .AENDI

        .AIF \&SHIFT GE 2          ; Condition: SHIFT  2
         SHLR2   Rn                ; When the condition is satisfied, Rn is shifted to the right by 2 bits.
SHIFT:  .ASSIGNA    \&SHIFT-2      ; 2 is subtracted from SHIFT.
        .AENDI

        .AIF \&SHIFT EQ 1          ; Condition: SHIFT = 1
         SHLR      Rn              ; When the condition is satisfied, Rn is shifted to the right by 1 bit.
        .AENDI
```

The expanded results are as follows:

```
        SHLR16   R0      ; When the condition is satisfied, Rn is shifted to the right by 16 bits.
        SHLR8    R0      ; When the condition is satisfied, Rn is shifted to the right by 8 bits.
        SHLR2    R0      ; When the condition is satisfied, Rn is shifted to the right by 2 bits.
        SHLR     R0      ; When the condition is satisfied, Rn is shifted to the right by 1 bit.
```

Character Preprocessor Variable Definition (Redefinition Is Possible)

Syntax

```
<preprocessor variable>[:] .ASSIGNC "<character string>"
```

Statement Elements

1. Label

   Enter the name of the preprocessor variable.

2. Operation

   Enter the .ASSIGNC mnemonic.

3. Operands

   Enter the character string enclosed with double quotation marks (").

Description

1. .ASSIGNC is the assembler directive that defines a character string for a character preprocessor variable. The syntax of character preprocessor variables is the same as that for symbols. A character preprocessor variable can be defined with up to 32 characters, and uppercase and lowercase letters are distinguished.

2. The preprocessor variables defined with the .ASSIGNC directive can be redefined with the .ASSIGNC directive.

3. Character strings are specified by characters or preprocessor variables enclosed with double quotation marks (").

4. Defined preprocessor variables are valid from the point of specification forward in the source program.

5. Defined preprocessor variables can be referenced in the following locations:

   — .ASSIGNA directive
   — .ASSIGNC directive
   — .AIF directive
   — .AELIF directive

— .AREPEAT directive
— .AWHILE directive
— Macro body (source statements between .MACRO and .ENDM)

When referencing character preprocessor variables, insert a backslash (\)* and an ampersand (&) in front of them.

\&<preprocessor variable>[']

To clearly distinguish the preprocessor variable name from the rest of the source statement, an apostrophe (') can be added.

Note When using a Japanese environment, use ¥ instead of \.

6. When a preprocessor character string is defined by a command line option, the .ASSIGNC directive specifying the preprocessor variable having the same name as the character string is invalidated.

Coding Example

```
FLAG:   .ASSIGNC   "ON"             ; "ON" is set to FLAG.
        ~

        .AIF "\&FLAG" EQ "ON"  ; MOV R0,R1 is assembled
         MOV R0,R1              ; when FLAG is "ON".
        .AENDI
        ~

FLAG:   .ASSIGNC   "\&FLAG "        ; A space (" ") is added to FLAG.
FLAGA:  .ASSIGNC   "OFF"            ; "OFF" is added to FLAGA.
FLAG:   .ASSIGNC   "\&FLAG'AND \&FLAGA"
                                    ; An apostrophe (') is used to distinguish FLAG and
                                    ; AND.
                                    ; FLAG finally becomes "ON AND OFF".
        ~
```

Definition of Preprocessor Replacement Character String

Syntax

```
<symbol>[:] .DEFINE "<replacement character string>"
```

Statement Elements

1. Label

   Enter a symbol to be replaced with a character string.

2. Operation

   Enter the .DEFINE mnemonic.

3. Operands

   Enter a character string to replace the symbol, enclosed with double quotation marks (").

Description

1. .DEFINE is the assembler directive that specifies that the symbol is replaced with the corresponding character string.

2. The differences between the .DEFINE directive and the .ASSIGNC directive are as follows.

   — The symbol defined by the .ASSIGNC directive can only be used in the preprocessor statement; the symbol defined by the .DEFINE directive can be used in any statement.
   — The symbols defined by the .ASSIGNA and the .ASSIGNC directives are referenced by the "\&symbol" format; the symbol defined by the .DEFINE directive is referenced by the "symbol" format.
   — The .DEFINE symbol cannot be redefined.

3. The .DEFINE directive specifying a symbol is invalidated when the same replacement symbol has been defined by a command line option.

Coding Example

```
SYM1:   .DEFINE      "R1"

          ~

        MOV.L        SYM1,R0        ; Replaced with MOV.L R1,R0.

          ~
```

Notes

1. A hexadecimal number starting with an alphabetical character a to f or A to F will be replaced when the same character string is specified as a replacement symbol by .DEFINE directive. Add 0 to the beginning of the number to stop replacing such number.

```
A0:     .DEFINE "0"
        MOV.B   #H'A0,R0        ; Replaced with MOV.B #H'0,R0.
        MOV.B   #H'0A0,R0       ; Not replaced.
```

2. A radix indication (B', Q', D', or H') will also be replaced when the same character string is specified as a replacement symbol by .DEFINE directive. When specifying a symbol having only one character, such as B, Q, D, H, b, q, d, or h, make sure that the corresponding radix indication is not used.

```
B       .DEFINE "H"
        MOV.B   #B'10,R0        ; Replaced with MOV.H #H'10,R0.
```

.AIF	.AELIF	.AELSE	.AENDI

Conditional Assembly with Comparison

Syntax

```
 Δ.AIFΔ<term1>Δ<relational operator>Δ<term2>
 <Source statements assembled if the AIF condition is satisfied>
[Δ.AELIFΔ<term1>Δ<relational operator>Δ<term2>                         ]
[ <Source statements assembled if the AELIF condition is satisfied>     ]
[Δ.AELSE                                                                ]
[<Source statements assembled if all the conditions are not satisfied>  ]
 Δ.AENDI
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .AIF, .AELIF (can be omitted), .AELSE (can be omitted), or .AENDI mnemonic.

3. Operands

   .AIF: Enter the condition. Refer to the description below.
   .AELIF: Enter the condition. Refer to the description below.
   .AELSE: The operand field is not used.
   .AENDI: The operand field is not used.

Description

1. .AIF, .AELIF, .AELSE, and .AENDI are the assembler directives that select whether or not to assemble source statements according to the condition specified. The .AELIF and .AELSE directives can be omitted.

2. .AELIF can be specified repeatedly between .AIF and .AELSE.

3. The condition must be specified as follows:

```
.AIF <term1> <relational operator> <term2>
.AELIF <term1> <relational operator> <term2>
```

   Terms are specified with numeric values or character strings. However, when a numeric value and a character string are compared, the condition always fails.

   Numeric values are specified by constants or preprocessor variables.

   Character strings are specified by characters or preprocessor variables enclosed with double quotation marks ("). To specify a double quotation mark in a character string, enter two double quotation marks in succession.

4. The following relational operators can be used:

   EQ: term1 = term2
   NE: term1 term2
   GT: term1 > term2
   LT: term1 < term2
   GE: term1 term2
   LE: term1 term2

Note: Numeric values are handled as 32-bit signed integers. For character strings, only EQ and NE conditions can be used.

.AIF	.AELIF	.AELSE	.AENDI

Coding Example

```
~

.AIF \&TYPE EQ 1
 MOV R0,R3              ; These statements
 MOV R1,R4              ; are assembled
 MOV R2,R5              ; when TYPE is 1.
.AELIF \&TYPE EQ 2
 MOV R0,R6              ; These statements
 MOV R1,R7              ; are assembled
 MOV R2,R8              ; when TYPE is 2.
.AELSE
 MOV R0,R9              ; These statements
 MOV R1,R10             ; are assembled
 MOV R2,R11             ; when TYPE is not 1 nor 2.
.AENDI

~
```

.AIFDEF	.AELSE	.AENDI

Conditional Assembly with Definition

Syntax

```
Δ.AIFDEFΔ<replacement symbol>
<statements to be assembled when the specified replacement symbol is defined>
[Δ.AELSE
<statements to be assembled when the specified replacement symbol is not defined>]
Δ.AENDI
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .AIFDEF, .AELSE (can be omitted), or .AENDI mnemonic.

3. Operands

   .AIFDEF: Enter the condition. Refer to the description below.
   .AELSE: The operand field is not used.
   .AENDI: The operand field is not used.

Description

1. .AIFDEF, .AELSE, and .AENDI are the assembler directives that select whether or not to assemble source statements according to the replacement symbol definition.

2. The condition must be specified as follows.

   ```
   .AIFDEF <replacement symbol>
   ```

   The replacement symbol must be defined by the .DEFINE directive.

   When the specified replacement symbol is defined by the command line option or in the source statements before this directive, the condition is regarded as satisfied. When the replacement symbol is defined after this directive or is not defined, the condition is regarded as unsatisfied.

Coding Example

```
~

.AIFDEF     FLAG
 MOV        R0,R3       ; These statements are assembled when
 MOV        R1,R4       ; FLAG is defined by .DEFINE directive.
.AELSE
 MOV        R0,R6       ; These statements are assembled when
 MOV        R1,R7       ; FLAG is not defined by .DEFINE directive.
.AENDI

~
```

.AREPEAT	.AENDR

Iterated Expansion

Syntax

```
 .AREPEAT <count>
<Source statements iteratively assembled>
 .AENDR
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .AREPEAT or .AENDR mnemonic.

3. Operands

   .AREPEAT: Enter the number of iterations.
   .AENDR: The operand field is not used.

Description

1. .AREPEAT and .AENDR are the assembler directives that assemble source statements by iteratively expanding them the specified number of times.

2. The source statements between the .AREPEAT and .AENDR directives are iterated the number of times specified with the .AREPEAT directive. Note that the source statements are simply copied the specified number of times, and therefore, the operation is not a loop at program execution.

3. Counts are specified by constants or preprocessor variables.

4. Nothing is expanded if a value of 0 or smaller is specified.

Coding Example

```
                        ; This example is a division of 64-bit data by 32-bit data.
                        ; R1:R2 (64 bits) ÷ R0 (32 bits) = R2 (32 bits): Unsigned
TST        R0,R0        ; Zero divisor check
BT         zero_div
CMP/HS     R0,R1        ; Overflow check
BT         over_div
DIV0U                   ; Flag initialization
.AREPEAT 32
 ROTCL     R2           ; These statements are
 DIV1      R0,R1        ; iterated 32 times.
.AENDR
ROTCL      R2           ; R2 = quotient
```

.AWHILE	.AENDW

Conditional Iterated Expansion

Syntax

```
 .AWHILE <term1> <relational operator> <term2>
<Source statements iteratively assembled>
 .AENDW
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .AWHILE or .AENDW mnemonic.

3. Operands

   .AWHILE: Enter the condition to iteratively expand source statements.
   .AENDW: The operand field is not used.

Description

1. .AWHILE and .AENDW are the assembler directives that assemble source statements by iteratively expanding them while the specified condition is satisfied.

2. The source statements between the .AWHILE and .AENDW directives are iterated while the condition specified with the .AWHILE directive is satisfied. Note that the source statements are simply copied iteratively, and therefore, the operation is not a loop at program execution.

3. The condition must be specified as follows:

   ```
   .AWHILE <term1> <relational operator> <term2>
   ```

   Terms are specified with numeric values or character strings. However, when a numeric value and a character string are compared, the condition always fails.

Numeric values are specified by constants or preprocessor variables.

Character strings are specified by characters or preprocessor variables enclosed with double quotation marks ("). To specify a double quotation mark in a character string, enter two double quotation marks (" ") in succession.

Conditional iterated expansion terminates when the condition finally fails.

CAUTION!

If a condition which never fails is specified, source statements are iteratively expanded for 65,535 times or until the maximum count of statement expansion specified by the .ALIMIT directive is reached. Accordingly, the condition for this directive must be carefully specified.

4. The following relational operators can be used:

   EQ: term1 = term2
   NE: term1 term2
   GT: term1 > term2
   LT: term1 < term2
   GE: term1 term2
   LE: term1 term2

Note: Numeric values are handled as 32-bit signed integers. For character strings, only EQ and NE conditions can be used.

.AWHILE	.AENDW

Coding Example

```
                                        ; This example is a multiply and accumulate
                                        ; operation.
TblSiz: .ASSIGNA  50                    ; TblSiz: Data table size
        MOV       A_Tbl1,R1             ; R1: Start address of data table 1
        MOV       A_Tbl2,R2             ; R2: Start address of data table 2
        CLRMAC                          ; MAC register initialization
        .AWHILE   \&TblSiz GT 0         ; While TblSiz is larger than 0,
         MAC.W    @R0+,@R1+             ; this statement is iteratively assembled.
TblSiz: .ASSIGNA  \&TblSiz-1            ; 1 is subtracted from TblSiz.
        .AENDW
        STS       MACL,R0               ; The result is obtained in R0.
```

Error Generation During Preprocessor Expansion

Syntax

```
.AERROR
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .AERROR mnemonic.

3. Operands

   The operand field is not used.

Description

1. When the .AERROR directive is assembled, error 667 is generated and the assembler is terminated with an error.

2. The .AERROR directive can be used to check values such as preprocessor variables.

Coding Example

```
        ~

   .AIF        \&FLG EQ 1
    MOV        R1,R10
    MOV        R2,R11
   .AELSE
     .AERROR                  ; When \&FLG is not 1, an error is generated.
   .AENDI

        ~
```

Expansion Termination

Syntax

```
.EXITM
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .EXITM mnemonic.

3. Operands

   The operand field is not used.

Description

1. .EXITM is the assembler directive that terminates an iterated expansion (.AREPEAT to .AENDR) or a conditional iterated expansion (.AWHILE to .AENDW).

2. Each expansion is terminated when this directive appears.

3. This directive is also used to exit from macro expansions. The location of this directive must be specified carefully when macro instructions and iterated expansion are combined.

   Reference: Macro expansion
   → Programmer's Guide, 8.2, "Macro Function Directives"

Coding Example

```
         ~

COUNT  .ASSIGNA 0              ; 0 is set to COUNT.
       .AWHILE  1 EQ 1         ; An infinite loop (condition is always satisfied) is
                               ; specified.
        ADD     R0,R1
        ADD     R2,R3
COUNT  .ASSIGNA \&COUNT+1      ; 1 is added to COUNT.
       .AIF     \&COUNT EQ 2   ; Condition: COUNT = 2
       .EXITM                  ; When the condition is satisfied
       .AENDI                  ; .AWHILE expansion is terminated.
       .AENDW

         ~
```

When COUNT is updated and satisfies the condition specified with the .AIF directive, .EXITM is assembled. When .EXITM is assembled, .AWHILE expansion is terminated.

The expansion results are as follows:

```
ADD   R0,R1 ..................... When COUNT is 0
ADD   R2,R3
ADD   R0,R1 ..................... When COUNT is 1
ADD   R2,R3
```

After this, COUNT becomes 2 and expansion is terminated.

Maximum Count Specification for .AWHILE Expansion in Preprocessor

Syntax

```
.ALIMIT     <count>
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .ALIMIT mnemonic.

3. Operands

   Enter the maximum count of statement expansion.

Description

1. During conditional iterated (.AWHILE to .AENDW) expansion, if the statement expansion count exceeds the maximum value specified by the .ALIMIT directive, warning 854 is generated and the expansion is terminated.

2. If the .ALIMIT directive is not specified, the maximum count is 65,535.

Coding Example

```
        .ALIMIT     20
          ~
FLG:    .ASSIGNA    0
        .AWHILE     \&FLG EQ 0     ; Expansion is terminated after performed
         NOP                       ; 20 times, and a warning message is output.
        .AENDW
          ~
```

Section 8 Macro Function

8.1 Overview of the Macro Function

The macro function allows commonly used sequences of instructions to be named and defined as one macro instruction. This is called a macro definition. Macro instructions are defined as follows:

```
       ~
      .MACRO <macro name>
         <macro body>
      .ENDM
       ~
```

A macro name is the name assigned to a macro instruction, and a macro body is the statements to be executed as the macro instruction.

Using a defined macro instruction by specifying the name is called a macro call. Macro instructions are called as follows:

```
       ~
      <defined macro name>
       ~
```

An example of macro definition and macro call is shown below.

Example:

```
 ~
.MACRO   SUM                 ; Processing to obtain the sum of R0, R1, R2,
 MOV R0,R10                  ; and R3 is defined as macro instruction SUM.
 ADD R1,R10
 ADD R2,R10
 ADD R3,R10
.ENDM
 ~

 SUM                         ; This statement calls macro instruction SUM.
                             ; Macro body   MOV  R0,R10
                             ;              ADD  R1,R10
                             ;              ADD  R2,R10
                             ;              ADD  R3,R10
                             ; is expanded from the macro instruction.
```

Parts of the macro body can be replaced when expanded by the following procedure:

1. Macro definition

   a. Declare formal parameters after the macro name in the .MACRO directive.
   b. Use the formal parameters in the macro body. Formal parameters must be identified in the macro body by placing a backslash (\) in front of them.

2. Macro call

   Specify macro parameters in the macro call.

   When the macro instruction is expanded, the formal parameters are replaced with their corresponding macro parameters.

Example:

```
 ~
.MACRO   SUM ARG1          ; Formal parameter ARG1 is defined.
 MOV R0,\ARG1              ; ARG1 is referenced in the macro body.
 ADD R1,\ARG1
 ADD R2,\ARG1
 ADD R3,\ARG1
.ENDM
 ~

 SUM R10                   ; This statement calls macro instruction SUM
                           ; specifying macro parameter R10.
                           ; The formal parameter in the macro body is
                           ; replaced with the macro parameter, and
                           ;           MOV  R0,R10
                           ;           ADD  R1,R10
                           ;           ADD  R2,R10
                           ;           ADD  R3,R10 is expanded.
```

8.2 Macro Function Directives

This assembler provides the following macro function directives.

`.MACRO` `.ENDM`	Defines a macro instruction.
`.EXITM`	Terminates macro instruction expansion.

.MACRO	.ENDM

Macro Definition

Syntax

```
.MACRO <macro name>[ <formal parameter>[=<default>]
                              [,<formal parameter>...]]
.ENDM
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .MACRO or .ENDM mnemonic.

3. Operands

   .MACRO: Enter the name and formal parameters (can be omitted) for the macro instruction to be defined. When formal parameters are defined, their defaults can be defined (defaults can be omitted).

   .ENDM: The operand filed is not used.

Description

1. .MACRO and .ENDM are the assembler directives that define a macro instruction (a sequence of source statements that are collectively named and handled together).

2. Macro definition

   Naming as a macro instruction the source statements (macro body) between the .MACRO and .ENDM directives is called a macro definition.

3. Macro name

   Macro names are the names assigned to macro instructions.

4. Formal parameters

Formal parameters are specified so that parts of the macro body can be replaced by specific parameters at expansion time. Formal parameters are replaced with the character strings (macro parameters) specified at macro expansion (macro call).

— Formal parameter syntax

The syntax for formal parameters is the same as that for symbols. A formal parameter can be defined with up to 32 characters, and uppercase and lowercase letters are distinguished.

— Formal parameter reference

Formal parameters are used (referenced) at the part to be replaced in the macro body.

The syntax of formal parameter reference in macro bodies is as follows:

```
\<formal parameter name>['] *
```

To clearly distinguish the formal parameter name from the rest of the source statement, an apostrophe (') can be added.

Note: When using a Japanese environment, use ¥ instead of \.

5. Formal parameter defaults

Defaults for formal parameters can be specified in macro definitions. The default specifies the character string to replace the formal parameter when the corresponding macro parameter is omitted in a macro call.

The default must be enclosed with double quotation marks (") or angle brackets (<>) if any of the following characters are included in the default.

— Space
— Tab
— Comma (,)
— Semicolon (;)
— Double quotation marks (")
— Angle brackets (< >)

The assembler inserts defaults at macro expansion by removing the double quotation marks or angle brackets that enclose the character strings.

.MACRO	.ENDM

6. Restrictions on macro definitions

   — Macros cannot be defined in the following locations:
   - Macro bodies (between .MACRO and .ENDM directives)
   - Between .AREPEAT and .AENDR directives
   - Between .AWHILE and .AENDW directives

   — The .END directive cannot be used within a macro body.

   — No symbol can be inserted in the label field of the .ENDM directive. The .ENDM directive is ignored if a symbol is written in the label field, but no error is generated in this case.

Coding Example

```
 ~
.MACRO   SUM                              ; Processing to obtain the sum of R0, R1, R2,
 MOV R0,R10                               ; and R3 is defined as macro instruction SUM.
 ADD R1,R10
 ADD R2,R10
 ADD R3,R10
.ENDM
 ~

 SUM                                      ; This statement calls macro instruction SUM
                                          ; Macro body  MOV  R0,R10
                                          ;             ADD  R1,R10
                                          ;             ADD  R2,R10
                                          ;             ADD  R3,R10 is expanded.
```

Expansion Termination

Syntax

```
.EXITM
```

Statement Elements

1. Label

   The label field is not used.

2. Operation

   Enter the .EXITM mnemonic.

3. Operands

   The operand field is not used.

Description

1. .EXITM is the assembler directive that terminates a macro expansion. This directive can be specified within the macro body (between the .MACRO and .ENDM directives).

2. Expansion is terminated when this directive appears.

3. This directive is also used to exit from iterated expansions specified with the .AREPEAT or .AWHILE directive. The location of this directive must be specified carefully when macro instructions and iterated expansion are combined.

Coding Example

```
.MACRO  SUM P1
MOV     R0,R10        ┐
ADD     R1,R10        │ (1)
ADD     R2,R10        ┘
\P1           -----------(2)
ADD     R3,R10
.ENDM
~~

SUM       .EXITM
```

.EXITM is expanded at (2) and macro expansion is terminated. Only the statements indicated by (1) are expanded.

8.3 Macro Body

The source statements between the .MACRO and .ENDM directives are called a macro body. The macro body is expanded and assembled by a macro call.

1. Formal parameter reference

   Formal parameters are used to specify the parts to be replaced with macro parameters at macro expansion.

   The syntax of formal parameter reference in macro bodies is as follows:

   ```
   \<formal parameter name>['] *
   ```

   To clearly distinguish the formal parameter name from the rest of the source statement, add an apostrophe (').

   Note: When using a Japanese environment, use ¥ instead of \.

Coding example:

```
        .MACRO   PLUS1 P,P1       ; P and P1 are formal parameters.
        ADD      #1,\P1           ; Formal parameter P1 is referenced.
        .SDATA   "\P'1"           ; Formal parameter P is referenced.
        .ENDM
        PLUS1    R,R1             ; PLUS1 is expanded.
         ~
```

Expanded results are as follows:

```
        ADD      #1,R1            ; Formal parameter P1 is referenced.
        .SDATA   "R1"             ; Formal parameter P is referenced.
```

2. Preprocessor variable reference

   Preprocessor variables can be referenced in macro bodies.

   The syntax for preprocessor variable reference is as follows:

   ```
   \&<preprocessor variable name>['] *
   ```

   To clearly distinguish the preprocessor variable name from the rest of the source statement, add an apostrophe (').

   Note: When using a Japanese environment, use ¥ instead of \.

Coding example:

```
         .MACRO   PLUS1
         ADD      #1,R\&V1          ; Preprocessor variable V1 is referenced.
         .SDATA   "\&V'1"           ; Preprocessor variable V is referenced.
         .ENDM
V        .ASSIGNC "R"               ; Preprocessor variable V is defined.
V1       .ASSIGNA 1                 ; Preprocessor variable V1 is defined.
         PLUS1                      ; PLUS1 is expanded.
```

Expanded results are as follows:

```
         ADD      #1,R1             ; Preprocessor variable V1 is referenced.
         .SDATA   "R1"              ; Preprocessor variable V is referenced.
```

3. Macro generation number

The macro generation number facility is used to avoid the problem that symbols used within a macro body will be multiply defined if the macro is expanded multiple times. To avoid this problem, specify the macro generation number marker as part of any symbol used in a macro. This will result in symbols that are unique to each macro call.

The macro generation number marker is expanded as a 5-digit decimal number (between 00000 and 99999) unique to the macro expansion.

The syntax for specifying the macro generation number marker is as follows:

```
\@   *
```

Note: When using a Japanese environment, use ¥ instead of \.

Two or more macro generation number markers can be written in a macro body, and they will be expanded to the same number in one macro call.

CAUTION!

Because macro generation number markers are expanded to numbers, they must not be written at the beginning of symbol names.

Reference: Programmer's Guide, 1.3.2, "Coding of Symbols"

Coding example:

```
          .MACRO    RES_STR STR, Rn
           MOV.L    #str\@,\Rn
           BRA      end_str\@
           NOP
str\@     .SDATA    "\STR"
          .ALIGN    2
end_str\@
          .ENDM
           RES_STR "ONE",R0          Different symbols are generated each time
           RES_STR "TWO",R1          RES_STR is expanded.

Expanded results are as follows:

           MOV.L    #str00000,R0
           BRA      end_str00000
           NOP
str00000  .SDATA    "ONE"
          .ALIGN    2
end_str00000
           MOV.L    #str00001,R1
           BRA      end_str00001
           NOP
str00001  .SDATA    "TWO"
          .ALIGN    2
end_str00001
```

4. Macro replacement processing exclusion

When a backslash (\) appears in a macro body, it specifies macro replacement processing. Therefore, a means for excluding this macro processing is required when it is necessary to use the backslash as an ASCII character.

The syntax for macro replacement processing exclusion is as follows:

`\(<macro replacement processing excluded character string>)` *

Note: When using a Japanese environment, use ¥ instead of \.

The backslash and the parentheses will be removed in macro processing.

Coding example:

```
        .MACRO  BACK_SLASH_SET
        \(MOV       #"\",R0)        ; \ is expanded as an ASCII character.
        .ENDM
Expanded results are as follows:
        MOV     #"\",R0             ; \ is expanded as an ASCII character.
```

5. Comments in macros

   Comments in macro bodies can be coded as normal comments or as macro internal comments. When comments in the macro body are not required in the macro expansion code (to avoid repeating the same comment in the listing file), those comments can be coded as macro internal comments to suppress their expansion.

   The syntax for macro internal comments is as follows:

   `\;<comment>` *

   Note: When using a Japanese environment, use ¥ instead of \.

   Coding example:

```
        .MACRO PUSH Rn
        MOV.L     \Rn,@-R15         \;    \Rn is a register.
        .ENDM
        PUSH      R0
Expanded results are as follows (the comment is not expanded):
        MOV.L     R0,@-R15
```

6. Character string manipulation functions

   Character string manipulation functions can be used in a macro body. The following character string manipulation functions are provided.

   .LEN .... Character string length.
   .INSTR .... Character string search.
   .SUBSTR .... Character string extraction.

   References:
   .LEN → Programmer's Guide, 8.5, "Character String Manipulation Functions", .LEN
   .INSTR → Programmer's Guide, 8.5, "Character String Manipulation Functions", .INSTR
   .SUBSTR → Programmer's Guide, 8.5, "Character String Manipulation Functions", .SUBSTR

8.4 Macro Call

Expanding a defined macro instruction is called a macro call. The syntax for macro calls is as follows:

Syntax

```
  [<symbol>[:]] <macro name>[ <macro parameter> [,<macro parameter>
...]]
```

Statement Elements

1. Label

   Enter a reference symbol if required.

2. Operation

   Enter the macro name to be expanded. The macro name must have been already defined before a macro call.

3. Operands

   Enter character strings as macro parameters to replace formal parameters at macro expansion. The formal parameters must have been declared in the macro definition with .MACRO.

Description

1. Macro parameter specification

   Macro parameters can be specified by either positional specification or keyword specification.

   — Positional specification
   The macro parameters are specified in the same order as that of the formal parameters declared in the macro definition with .MACRO.

   — Keyword specification
   Each macro parameter is specified following its corresponding formal parameter, separated by an equal sign (=).

2. Macro parameter syntax

Macro parameters must be enclosed with double quotation marks (") or angle brackets (<>) if any of the following characters are included in the macro parameters:

— Space
— Tab
— Comma (,)
— Semicolon (;)
— Double quotation marks (")
— Angle brackets (< >)

Macro parameters are inserted by removing the double quotation marks or angle brackets that enclose character strings at macro expansion.

Coding Example

```
        .MACRO  SUM FROM=0,TO=9       ; Macro instruction SUM and formal
        MOV     R\FROM,R10            ; parameters FROM and TO are defined.
COUNT   .ASSIGNA        \FROM+1
        .AWHILE \&COUNT LE \TO
        MOV     R\&COUNT,R10            Macro body is coded
COUNT   .ASSIGNA        \&COUNT+1       using formal parameters.
        .AENDW
        .ENDM

        SUM     0,5                     Both will be expanded
        SUM     TO=5                    into the same statements.
```

Expanded results are as follows (the formal parameters in the macro body are replaced with macro parameters):

```
        MOV     R0,R10
        MOV     R1,R10
        MOV     R2,R10
        MOV     R3,R10
        MOV     R4,R10
        MOV     R5,R10
```

8.5 Character String Manipulation Functions

This assembler provides the following character string manipulation functions.

`.LEN`	Counts the length of a character string.
`.INSTR`	Searches for a character string.
`.SUBSTR`	Extracts a character string.

```
.LEN
```

Character String Length Count

Syntax

```
.LEN[ ]("<character string>")
```

Description

1. .LEN counts the number of characters in a character string and replaces itself with the number of characters in decimal with no radix.

2. Character strings are specified by enclosing the desired characters with double quotation marks ("). To specify a double quotation mark in a character string, enter two double quotation marks in succession.

3. Macro formal parameters and preprocessor variables can be specified in the character string as shown below.

```
.LEN("\<formal parameter>")
.LEN("\&<preprocessor variable>") *
```

Note: When using a Japanese environment, use ¥ instead of \.

4. This function can only be used within a macro body (between .MACRO and .ENDM directives).

Coding Example:

```
    ~
    .MACRO RESERVE_LENGTH P1
    .ALIGN 4
    .SRES    .LEN("\P1")
    .ENDM
    ~
    RESERVE_LENGTH ABCDEF
    RESERVE_LENGTH ABC
```

Expanded results are as follows:

```
    .ALIGN   4
    .SRES    6                  ; "ABCDEF" has six characters.
    .ALIGN   4
    .SRES    3                  ; "ABC" has three characters.
```

```
.INSTR
```

Character String Search

Syntax

```
.INSTR[ ]("<character string 1>","<character string 2>"
                                          [,<start position>])
```

Description

1. .INSTR searches character string 1 for character string 2, and replaces itself with the numerical value of the position of the found string (with 0 indicating the start of the string) in decimal with no radix. .INSTR is replaced with –1 if character string 2 does not appear in character string 1.

2. Character strings are specified by enclosing the desired characters with double quotation marks ("). To specify a double quotation mark in a character string, enter two double quotation marks in succession.

3. The <start position> parameter specifies the search start position as a numerical value, with 0 indicating the start of character string 1. Zero is used as default when this parameter is omitted.

4. Macro formal parameters and preprocessor variables can be specified in the character strings and as the start position as shown below.

   ```
   .INSTR("\<formal parameter>", ...)
   ```

   ```
   .INSTR("\&<preprocessor variable>", ...) *
   ```

   Note: When using a Japanese environment, use ¥ instead of \.

5. This function can only be used within a macro body (between the .MACRO and .ENDM directives).

Coding Example:

```
    ~
    .MACRO FIND_STR P1
    .DATA.W .INSTR("ABCDEFG","\P1",0)
    .ENDM
    ~
    FIND_STR CDE
    FIND_STR H
```

Expanded results are as follows:

```
    .DATA.W  2        ; The start position of "CDE" is 2 (0 indicating the
                        beginning of the string) in "ABCDEFG"
    .DATA.W  -1       ; "ABCDEFG" includes no "H".
```

.SUBSTR

Character Substring Extraction

Syntax

```
.SUBSTR[ ]("<character string>",<start position>,<extraction length>)
```

Description

1. .SUBSTR extracts from the specified character string a substring starting at the specified start position of the specified length. .SUBSTR is replaced with the extracted character string enclosed with double quotation marks (").

2. Character strings are specified by enclosing the desired characters in double quotation marks ("). To specify a double quotation mark in a character string, enter two double quotation marks in succession.

3. The value of the extraction start position must be 0 or greater. The value of the extraction length must be 1 or greater.

4. If illegal or inappropriate values are specified for the <start position> or <extraction length> parameters, this function is replaced with a space (" ").

5. Macro formal parameters and preprocessor variables can be specified in the character string, and as the start position and extraction length parameters as shown below.

   ```
   .SUBSTR("\<formal parameter>", ...)

   .SUBSTR("\&<preprocessor variable>", ...) *
   ```

   Note: When using a Japanese environment, use ¥ instead of \.

6. This function can only be used within a macro body (between the .MACRO and .ENDM directives).

Coding Example:

```
~
.MACRO RESERVE_STR P1=0,P2
.SDATA   .SUBSTR("ABCDEFG",\P1,\P2)
.ENDM
~

RESERVE_STR 2,2
RESERVE_STR ,3                  ; Macro parameter P1 is omitted.
```

Expanded results are as follows:

```
.SDATA   "CD"
.SDATA   "ABC"
```

Section 9 Automatic Literal Pool Generation Function

9.1 Overview of Automatic Literal Pool Generation

To move 2-byte or 4-byte constant data (referred to below as a "literal") to a register, a literal pool (a collection of literals) must be reserved and referred to in PC relative addressing mode. For literal pool location, the following must be considered:

- Is data stored within the range that can be accessed by data move instructions?
- Is 2-byte data aligned to a 2-byte boundary and is 4-byte data aligned to a 4-byte boundary?
- Can data be shared by several data move instructions?
- Where in the program should the literal pool be located?

The assembler automatically generates from a single instruction a .DATA directive and a PC relative MOV or MOVA instruction, which moves constant data to a register.

For example, this function enables program (a) below to be coded as (b):

(a)

```
         MOV.L    DATA1,R0
         MOV.L    DATA2,R1

         ~

         .ALIGN 4
DATA1    .DATA.L H'12345678
DATA2    .DATA.L 500000
```

(b)

```
         MOV.L    #H'12345678,R0
         MOV.L    #500000,R1

         ~
```

9.2 Extended Instructions Related to Automatic Literal Pool Generation

The assembler automatically generates a literal pool corresponding to an extended instruction (MOV.W #imm, Rn; MOV.L #imm, Rn; or MOVA #imm, R0) and calculates the PC relative displacement value.

An extended instruction source statement is expanded to an executable instruction and literal data as shown in table 9-1.

Table 9-1 Extended Instructions and Expanded Results

Extended Instruction	Expanded Result
MOV.W #imm, Rn	MOV.W @(disp, PC), Rn and 2-byte literal data
MOV.L #imm, Rn	MOV.L @(disp, PC), Rn and 4-byte literal data
MOVA #imm, R0	MOVA @(disp, PC), R0 and 4-byte literal data

9.3 Size Mode for Automatic Literal Pool Generation

Automatic literal pool generation has two modes: size specification mode and size selection mode. In size specification mode, a data move instruction (extended instruction) whose operation size is prespecified is used to generate a literal pool. In size selection mode, when a move instruction without size specification is written, the assembler automatically checks the imm operand value and selects a suitable-size move instruction.

Table 9-2 shows data move instructions and size mode.

Table 9-2 Data Move Instructions and Size Mode

Data Move Instruction	Size Specification Mode	Size Selection Mode
MOV #imm, Rn	Executable instruction	Selected by assembler
MOV.B #imm, Rn	Executable instruction	Executable instruction
MOV.W #imm, Rn	Extended instruction	Extended instruction
MOV.L #imm, Rn	Extended instruction	Extended instruction

Size Specification Mode:

In this mode, a data move instruction without size specification (MOV #imm,Rn) is handled as a normal executable instruction. This mode is used when –AUTO_LITERAL is not specified as the command line option.

Size Selection Mode:

In this mode, when a data move instruction without size specification (MOV #imm,Rn) is written, the assembler checks the imm operand value and automatically generates a literal pool if necessary. The imm value is checked for the signed value range.

This mode is used when –AUTO_LITERAL is specified as the command line option.

Table 9-3 shows the instructions selected depending on imm value range.

Table 9-3 Instructions Selected in Size Selection Mode

imm Specification	imm Value Range*	Selected Instruction
Constant or back-reference absolute value	H'FFFFFF80 to H'0000007F (–128 to 127)	MOV.B #imm, Rn
	H'FFFF8000 to H'FFFFFF7F (–32,768 to –129) H'00000080 to H'00007FFF (128 to 32,767)	MOV.W #imm, Rn Expansion result: [MOV.W @(disp, PC), Rn and 2-byte literal data]
	H'80000000 to H'FFFF7FFF (–2,147,483,648 to –32,769) H'00008000 to H'7FFFFFFF (32,768 to 2,147,483,647)	MOV.L #imm, Rn Expansion result: [MOV.L @(disp, PC), Rn and 4-byte literal data]
Relative value or forward-reference absolute value	Does not depend on imm value	MOV.L #imm, Rn Expansion result: [MOV.L @(disp, PC), Rn and 4-byte literal data]

Note: The values in parentheses ( ) are decimal.

Reference:

–AUTO_LITERAL

→ User's Guide, 2.2.8, "Automatic Literal Pool Generation Command Line Option"

9.4 Literal Pool Output

The literal pool is output to one of the following locations:

- After an unconditional branch and its delay slot instruction
- Where a .POOL directive has been specified by the programmer

The assembler outputs the literal corresponding to an extended instruction to the nearest output location following the extended instruction. The assembler gathers the literals to be output as a literal pool.

CAUTION!

When a label is specified in a delay slot instruction, no literal pool will be output to the location following the delay slot.

9.4.1 Literal Pool Output after Unconditional Branch

An example of literal pool output is shown below.

Source program

```
          .SECTION CD1,CODE,LOCATE=H'0000F000
CD1_START:
          MOV.L   #H'FFFF0000,R0
          MOV.W   #H'FF00,R1
          MOV.L   #CD1_START,R2
          MOV     #H'FF,R3
          RTS
          MOV     R0,R10
          .END
```

Automatic literal pool generation result (source list)

```
 1 0000F000                  1         .SECTION CD1,CODE,LOCATE=H'0000F000
 2 0000F000                  2   CD1_START
 3 0000F000 D003             3         MOV.L    #H'FFFF0000,R0
 4 0000F002 9103             4         MOV.W    #H'FF00,R1
 5 0000F004 D203             5         MOV.L    #CD1_START,R2
 6 0000F006 E3FF             6         MOV      #H'FF,R3
 7 0000F008 000B             7         RTS
 8 0000F00A 6A03             8         MOV      R0,R10
 9                               **** BEGIN-POOL ****
10 0000F00C FF00                 DATA FOR SOURCE-LINE 4
11 0000F00E 0009                 ALIGNMENT CODE
12 0000F010 FFFF0000             DATA FOR SOURCE-LINE 3
13 0000F014 0000F000             DATA FOR SOURCE-LINE 5
14                               ****  END-POOL  ****
15                           9         .END
```

9.4.2 Literal Pool Output to the .POOL Location

If literal pool output location after unconditional branches is not available within the valid displacement range (because the program has a small number of unconditional branches), the assembler outputs error 402. In this case, a .POOL directive must be specified within the valid displacement range.

The valid displacement range is as follows:

- Word-size operation: 0 to 511 bytes
- Longword-size operation: 0 to 1023 bytes

When a literal pool is output to a .POOL location, a branch instruction is also inserted to jump over the literal pool.

An example of literal pool output is shown on the following page.

Source program

```
        .SECTION CD1,CODE,LOCATE=H'0000F0000
CD1_START
        MOV.L   #H'FFFF0000,R0
        MOV.W   #H'FF00,R1
        MOV.L   #CD1_START,R2
        MOV     #H'FF,R3
        .POOL
        .END
```

↓ ↓ ↓ ↓ ↓ ↓ ↓

Automatic literal pool generation result (source list)

```
  1 0000F000                 1       .SECTION CD1,CODE,LOCATE=H'0000F000
  2 0000F000                 2  CD1_START:
  3 0000F000 D003            3       MOV.L    #H'FFFF0000,R0
  4 0000F002 9103            4       MOV.W    #H'FF00,R1
  5 0000F004 D203            5       MOV.L    #CD1_START,R2
  6 0000F006 E3FF            6       MOV      #H'FF,R3
  7 0000F008                 7       .POOL
  8                             **** BEGIN-POOL ****
  9 0000F008 A006                   BRA TO END-POOL
 10 0000F00A 0009                   NOP
 11 0000F00C FF00                   DATA FOR SOURCE-LINE 4
 12 0000F00E 0000                   ALIGNMENT CODE
 13 0000F010 FFFF0000               DATA FOR SOURCE-LINE 3
 14 0000F014 0000F000               DATA FOR SOURCE-LINE 5
 15                             ****  END-POOL  ****
 16                          8      .END
```

9.5 Literal Sharing

When the literals for several extended instructions are gathered into a literal pool, the assembler makes the extended instructions share identical immediate data.

The following operand forms can be identified and shared:

- Symbol
- Constant
- Symbol ± constant

In addition to the above, expressions that are determined to have the same value at assembly processing may be shared.

However, extended instructions having different operation sizes do not share literal data even when they have the same immediate data.

An example of literal data sharing among extended instructions is shown on the following page.

Source program

```
        .SECTION CD1,CODE,LOCATE=H'0000F000
CD1_START:
        MOV.L   #H'FFFF0000,R0
        MOV.W   #H'FF00,R1
        MOV.L   #H'FFFF0000,R2
        MOV     #H'FF,R3
        RTS
        MOV     R0,R10
        .END
```

↓ ↓ ↓ ↓ ↓ ↓ ↓

Automatic literal pool generation result (source list)

```
  1 0000F000              1        .SECTION CD1,CODE,LOCATE=H'0000F000
  2 0000F000              2   CD1_START:
  3 0000F000 D003         3        MOV.L   #H'FFFF0000,R0
  4 0000F002 9103         4        MOV.W   #H'FF00,R1
  5 0000F004 D202         5        MOV.L   #H'FFFF0000,R2
  6 0000F006 E3FF         6        MOV     #H'FF,R3
  7 0000F008 000B         7        RTS
  8 0000F00A 6A03         8        MOV     R0,R10
  9                           **** BEGIN-POOL ****
 10 0000F00C FF00                 DATA FOR SOURCE-LINE 4
 11 0000F00E 0000                 ALIGNMENT CODE
 12 0000F010 FFFF0000             DATA FOR SOURCE-LINE 3,5
 13                           ****  END-POOL  ****
 14                       9        .END
```

9.6 Literal Pool Output Suppression

When a program has too many unconditional branches, the following problems may occur:

- Many small literal pools are output
- Literals are not shared

In these cases, suppress literal pool output as shown below.

```
        ~
        <delayed branch instruction>
        <delay slot instruction>
        .NOPOOL
        ~
```

Example

Source program

```
        ~
CASE1:
        MOV.L    #H'FFFF0000,R0     -------    Extended instruction 1
        RTS
        NOP
        .NOPOOL                     -------    No literal pool is output here
CASE2:
        MOV.L    #H'FFFF0000,R0     -------    Extended instruction 2
        RTS
        NOP
        ~                           -------    Literal pool is output here
```

↓ ↓ ↓ ↓ ↓ ↓ ↓

Automatic literal pool generation result (source list)

```
         ~
 20 0000F000                20 CASE1:
 21 0000F000 D002           21       MOV.L    #H'FFFF0000,R0
 22 0000F002 000B           22       RTS
 23 0000F004 0009           23       NOP
 24                         24       .NOPOOL
 25 0000F006                25 CASE2:
 26 0000F006 D001           26       MOV.L    #H'FFFF0000,R0
 27 0000F008 000B           27       RTS
 28 0000F00A 0009           28       NOP
 29                            **** BEGIN-POOL ****
 30 0000F00C FFFF0000                DATA FOR SOURCE-LINE 21,26
 31                            ****  END-POOL  ****
         ~
```

9.7 Notes on Automatic Literal Pool Output

1. If an error occurs when an extended instruction is written

   a. Extended instructions must not be specified in delay slots (error 151).
   b. Extended instructions must not be specified in relative sections having a boundary alignment value of less than 2 (error 152).
   c. MOV.L #imm, Rn or MOVA #imm, R0 must not be specified in relative sections having a boundary alignment value of less than 4 (error 152).

2. If an error occurs when a .POOL directive is written

   .POOL directives must not be written after unconditional branches (error 522).

3. If an error occurs when a .NOPOOL directive is written

   .NOPOOL directives are valid only when written after delay slot instructions. If written at other locations, the .NOPOOL directive causes error 521.

4. If the displacement of an executable instruction exceeds the valid range when an extended instruction is expanded

   The assembler generates a literal pool and outputs error 402 for the instruction having a displacement outside the valid range.

   Solution: Move the literal pool output location (for example, by the .NOPOOL directive), or change the location or addressing mode of the instruction causing the error.

5. If the literal pool output location cannot be found

   If the assembler cannot find a literal pool output location satisfying the following conditions in respect to the extended instruction,

   — Same file
   — Same section
   — Forward direction

   the assembler outputs, at the end of the section which includes the extended instruction, the literal pool and a BRA instruction with a NOP instruction in the delay slot to jump around the literal pool, and outputs warning 876.

6. If the displacement from the extended instruction exceeds the valid range

   If the displacement of the literal pool from the extended instruction exceeds the valid range, error 402 is generated.

   Solution: Output the literal pool within the valid range (for example, using the .POOL directive.)

7. Differences between size specification mode and size selection mode

   Version 2.0 of the assembler can only use the size specification mode, but the size selection mode is added to this new assembler version. If the source program created before for version 2.0 is assembled in the size selection mode by version 3.1 or higher, the imm values of data move instructions without size specifications will differ by H'00000080 to H'000000FF (128 to 255) from these assembled by version 2.0.

   An example of source listing output in the size specification mode and size selection mode is shown on the following page.

Example:

Source program

```
        .SECTION CD1,CODE,LOCATE=H'0000F000
        MOV.L   #H'FF,R0
        MOV.W   #H'FF,R1
        MOV.B   #H'FF,R2
        MOV     #H'FF,R3
        RTS
        MOV     R0,R10
        .END
```

↓ ↓ ↓ ↓

Automatic literal pool output in size specification mode (source listing)

```
 1 0000F000                1        .SECTION CD1,CODE,LOCATE=H'0000F000
 2 0000F000 D003           2        MOV.L   #H'FF,R0
 3 0000F002 9103           3        MOV.W   #H'FF,R1
 4 0000F004 E2FF           4        MOV.B   #H'FF,R2
 5 0000F006 E3FF           5        MOV     #H'FF,R3
 6 0000F008 000B           6        RTS
 7 0000F00A 6A03           7        MOV     R0,R10
 8                            ***** BEGIN-POOL *****
 9 0000F00C 00FF              DATA FOR SOURCE-LINE 3
10 0000F00E 0000              ALIGNMENT CODE
11 0000F010 000000FF          DATA FOR SOURCE-LINE 2
12                            ***** END-POOL *****
13                         8        .END
```

The contents of R3 is H'FFFFFFFF.

Automatic literal pool output in size selection mode (source listing)

```
 1 0000F000                1        .SECTION CD1,CODE,LOCATE=H'0000F000
 2 0000F000 D003           2        MOV.L   #H'FF,R0
 3 0000F002 9103           3        MOV.W   #H'FF,R1
 4 0000F004 E2FF           4        MOV.B   #H'FF,R2
 5 0000F006 9301           5        MOV     #H'FF,R3
 6 0000F008 000B           6        RTS
 7 0000F00A 6A03           7        MOV     R0,R10
 8                            ***** BEGIN-POOL *****
 9 0000F00C 00FF              DATA FOR SOURCE-LINE 3,5
10 0000F00E 0000              ALIGNMENT CODE
11 0000F010 000000FF          DATA FOR SOURCE-LINE 2
12                            ***** END-POOL *****
13                         8        .END
```

The contents of R3 is H'000000FF.

Section 10 Automatic Repeat Loop Generation Function

10.1 Overview of Automatic Repeat Loop Generation Function

In the SH-DSP, the start and end addresses of the repeat loop are set in the RS and RE registers by the LDRS and LDRE instructions. The address settings differ depending on the number of instructions in the repeat loop. When setting the address, consider the relationship between the address and the number of instructions in the repeat loop shown in table 10-1.

Table 10-1 Repeat Loop Instructions and Address Setting

Register Name	One Instruction	Two Instructions	Three Instructions	Four or more Instructions
RS	s_addr0+8	s_addr0+6	s_addr0+4	s_addr
RE	s_addr0+4	s_addr0+4	s_addr0+4	e_addr3+4

s_addr0: Address of the instruction one instruction before the repeat loop start address

s_addr: Repeat loop start address

e_addr3: Address of the instruction three instructions before the repeat loop end address

The automatic repeat loop generation function automatically generates the PC relative instructions LDRS and LDRE, and the SETRC instruction from a single instruction. The LDRS and LDRE instructions transfer the repeat loop start and end addresses based on the number of instructions in the repeat loop to the RS and RE registers, and the SETRC instruction specifies the repetition count.

For example, program A can be written as program B when using the automatic repeat loop generation function.

Program A:

```
    LDRS s_addr0+6
    LDRE s_addr0+4
    SETRC #10
s_addr0:  NOP
    PADD A0,M0,A0  ;   Repeat loop start address
    PCMP X1,M0     ;   Repeat loop end address
```

Program B:

```
     REPEAT s_addr,e_addr,#10
     NOP
s_addr:    PADD A0,M0,A0  ;  Repeat loop start address
e_addr:    PCMP X1,M0     ;  Repeat loop end address
```

10.2 Extended Instructions of Automatic Repeat Loop Generation Function

The assembler automatically generates necessary instructions from extended instructions (REPEAT s_label,e_label,#imm, REPEAT s_label,e_label,Rn, and REPEAT s_label,e_label) and calculates the PC relative displacement.

Table 10-2 lists the source statement of each extended instruction and its expanded results of two or three executable instructions.

Table 10-2 Extended Instructions and Expanded Results

Extended Instruction	Expanded Results
REPEAT s_label,e_label,#imm	LDRS @(disp,PC), LDRE@(disp,PC), and SETRC #imm
REPEAT s_label,e_label,Rn	LDRS @(disp,PC), LDRE@(disp,PC), and SETRC Rn
REPEAT s_label,e_label	LDRS @(disp,PC) and LDRE@(disp,PC)

10.3 REPEAT Description

Syntax

```
[<symbol>[:]] REPEAT <start address>,<end address>[,<repeat count>]
```

Statement Elements

1. Start and end addresses

   Enter the labels of the start and end addresses of the repeat loop.

2. Repeat count

   Enter the repeat count as an immediate value or as a general register name.

Description

1. REPEAT automatically generates the executable instructions LDRS and LDRE to repeat the instructions in the range from the start address to the end address.

2. When the repeat count is specified, REPEAT generates a SETRC instruction. When the repeat count is omitted, SETRC is not generated.

10.4 Coding Examples

To Repeat Four or More Instructions (Basic Example):

```
           REPEAT RptStart,RptEnd,#5
           PCLR Y0
           PCLR A0
RptStart:  MOVX @R4+,X1 MOVY @R6+,Y1
           PADD A0,Y0,Y0 PMULS X1,Y1,A0
       DCT PCLR A0
           AND R0,R4
RptEnd:    AND R0,R6
```

This program repeats execution of five instructions from RptStart to RptEnd five times.

The above program has the same meaning as the following:

```
           LDRS RptStart
           LDRE RptEnd3+4
           SETRC #5
           PCLR Y0
           PCLR A0
RptStart:  MOVX @R4+,X1 MOVY @R6+,Y1
RptEnd3:   PADD A0,Y0,Y0 PMULS X1,Y1,A0;      The label is not actually generated.
       DCT PCLR A0
           AND R0,R4
RptEnd:    AND R0,R6
```

To Repeat One Instruction: Specify the same labels as the start and end addresses.

```
             REPEAT Rpt,Rpt,R0
             MOVX @R4+,X1 MOVY @R6,Y1
Rpt:         PADD A0,Y0,Y0 PMULS X1,Y1,A0 MOVX @R4+,X1 MOVY @R6+,Y1
```

The above program has the same meaning as the following:

```
             LDRS RptStart0+8
             LDRE RptStart0+4
             SETRC R0
RptStart0:   MOVX @R4+,X1 MOVY @R6,Y1     ;The label is not actually generated.
Rpt:         PADD A0,Y0,Y0 PMULS X1,Y1,A0 MOVX @R4+,X1 MOVY @R6+,Y1
```

To Repeat Two Instructions:

```
             REPEAT RptStart,RptEnd,#10
             PCLR Y0
RptStart:    MOVX @R4+,X1 MOVY @R6+,Y1
RptEnd:      PADD A0,Y0,Y0 PMULS X1,Y1,A0
```

The above program has the same meaning as the following:

```
             LDRS RptStart0+6
             LDRE RptStart0+4
             SETRC #10
RptStart0:   PCLR Y0   ;The label is not actually generated.
RptStart:    MOVX @R4+,X1 MOVY @R6+,Y1
RptEnd:      PADD A0,Y0,Y0 PMULS X1,Y1,A0
```

To Repeat Three Instructions:

```
            REPEAT RptStart,RptEnd,R0
            PCLR Y0
RptStart:   MOVX @R4+,X1 MOVY @R6+,Y1
            PMULS X1,Y1,A0
RptEnd:     PADD A0,Y0,Y0
```

The above program has the same meaning as the following:

```
            LDRE RptStart0+4
            LDRS RptStart0+4
            SETRC R0
RptStart0:  PCLR Y0   ;The label is not actually generated.
RptStart:   MOVX @R4+,X1 MOVY @R6+,Y1
            PMULS X1,Y1,A0
RptEnd:     PADD A0,Y0,Y0
```

To Omit the Repeat Count: When the repeat count is omitted, the assembler does not generate SETRC. To separate the LDRS and LDRE from the SETRC, omit the repeat count.

```
           REPEAT RptStart,RptEnd
           ; The LDRS and LDRE are expanded here.
           MOV #10,R0
OuterLoop:
           SETRC #16
           PCLR Y0
           PCLR A0
RptStart:  MOVX @R4+,X1 MOVY @R6+,Y1
           PADD A0,Y0,Y0 PMULS X1,Y1,A0
       DCT PCLR A0
           AND R0,R4
RptEnd:    AND R0,R6
           DT R0
           BF OuterLoop
```

10.5 Notes on the REPEAT Extended Instruction

Start and End Addresses: Only labels in the same section or local labels in the same local block can be specified as the start and end addresses.

The start address must come after (be at a higher address than) the REPEAT extended instruction. The end address must come after (be at a higher address than) the start address.

Reference: Local labels
→ Programmer's Guide, 1.8, "Local Label"

Instructions Inside Loops:

- If one of the following assembler directives that reserve a data item or a data area or an .ORG directive is used inside a loop, the assembler outputs a warning message and counts the directive as one of the instructions to be repeated. If an .ALIGN directive is used inside a loop to adjust the boundary alignment, the assembler outputs a warning message and counts the directive as one of the instructions to be repeated.

  Directives generating a warning inside loops:
  .DATA, .DATAB, .SDATA, .SDATAB, .SDATAC, .SDATAZ, .FDATA, .FDATAB, .XDATA, .RES, .SRES, .SRESC, .SRESZ, .FRES, .ALIGN, and .ORG

- The assembler stops automatic generation of literal pools within a loop. Therefore, even when an unconditional branch is used in a loop, no literal pool is generated. If a .POOL directive is used in a loop, the assembler outputs a warning message and ignores the .POOL directive.

Instruction Immediately before Loop: If three or fewer instructions are to be repeated, the instruction immediately before the loop must be an executable instruction or a DSP instruction. Therefore, when three or fewer instructions are to be repeated and if one of the following is located immediately before the start address of the loop, the assembler outputs an error.

- Assembler directives that reserve a data item or a data area or .ORG directive

  .DATA, .DATAB, .SDATA, .SDATAB, .SDATAC, .SDATAZ, .FDATA, .FDATAB, .XDATA, .RES, .SRES, .SRESC, .SRESZ, .FRES, or .ORG

- Literal pool generated by the automatic literal pool output function

  If an unconditional branch instruction and a delay slot instruction are located immediately before a loop, or if a .POOL directive is located immediately before a loop, a literal pool may be automatically generated. To prevent literal pool generation before a loop, use a .NOPOOL directive immediately after the delay slot instruction.

- One alignment byte generated by an .ALIGN directive

  When an .ALIGN directive is used immediately after an odd address before a loop, one alignment byte may be generated (for example, `.ALIGN 4` is specified when the location counter value is 3). In this case, the contents of the byte before a loop is not an executable instruction, and an error message is output. If two or more alignment bytes are generated before a loop, their contents consist of a NOP instruction and the program can be correctly executed.

Others:

- One or more executable or DSP instructions must be located between a REPEAT extended instruction and the start address. Otherwise, the assembler outputs an error message.

- A REPEAT extended instruction must not be located between another REPEAT extended instruction and its end address. If REPEAT extended instructions are nested, the assembler outputs an error message; the first REPEAT is valid, and the other REPEAT instructions are ignored.

User's Guide

Section 1 Executing the Assembler

1.1 Command Line Format

To start the assembler, enter a command line with the following format when the host computer operating system is in the input wait state.

```
> asmsh Δ <input source file> [,<input source file>...][[Δ] <command line option> ...]
  └───┘ └───────────────────┘                               └──────────────────────┘
   (1)           (2)                                                   (3)
```

(1) Assembler start command.

(2) Name of input source file. Multiple source files can be specified at the same time.

(3) Command line options, which specify the assembly method in more detail.

CAUTION!

When multiple source files are specified on the command line, the unit of assembly processing will be the concatenation of the specified files in the specified order.

In this case, the .END directive must appear only in the last file.

Supplement:

The assembler returns the operating system a return code that reports whether or not the assembly processing terminated normally. The return value indicates the level of the errors occurred as follows.

Normal termination 0
Warnings occurred... 0
Errors occurred .... Windows®95 and Windows®NT: 2
UNIX: 1
Fatal error occurred.......................... Windows®95 and Windows®NT: 4
UNIX: 1

The return code can be changed with –ABORT.

Reference:

–ABORT

→ User's Guide, 2.2.6, "Assembler Execution Command Line Options," –ABORT

1.2 File Specification Format

Files handled by the assembler are specified in the following format.

```
<file name>.[<file format>]
```

The term "file name" as used in this manual normally refers to both the file name and the file format.

Example:

```
(File name)
file.src ..... A file with the file name "file" and the file format "src".
prog.obj ..... A file with the file name "prog" and the file format "obj".
```

The file format is used as an identifier to distinguish the contents of the file. Thus two files with differing formats are different files even if the file name is the same.

Example:

$$\left.\begin{array}{l}\texttt{file.src}\\ \texttt{file.obj}\end{array}\right\}\ \text{These file names specify different files.}$$

The assembler handles the following types of file.

- Source file

  This is a source program file. If a source program file is specified without the file format, the file format "src" will be supplied.

- Object file

  This is an output destination file for object modules. If an object file is specified without the file format, the file format obj will be supplied. If an object file is not specified to the assembler, a file with the same name as the source file (the first file) and with the file format "obj" will be used.

- Listing file

  This is an output destination file for assemble listings. If a listing file is specified without the file format, the extension "lis" will be supplied. If a listing file is not specified to the assembler, a file with the same name as the source file (the first file) and with the file format "lis" will be used.

1.3 SHCPU Environment Variable

The assembler assembles the program for the CPU specified by the SHCPU environment variable. The following shows how to specify the environment variable.

For UNIX:

- C Shell

```
setenv SHCPU <target CPU>
```

- Bourne/Korn Shell

```
SHCPU=<target CPU>
export SHCPU
```

For Windows®95 and Windows®NT:

```
SET SHCPU=<target CPU>
```

The target CPU can be selected from SH1, SH2, SH2E, SH3, SH3E, SH4, SHDSP, and SH3DSP.

The priority of target CPU specification is in the order of –CPU, .CPU directive, and SHCPU environment variable.

Note: Be sure to specify this environment variable in uppercase letters.

Section 2 Command Line Options

2.1 Overview of Command Line Options

Command line options are detailed specifications of the assembly processing. Table 2-1 shows an overview of the command line options.

Table 2-1 Command Line Options

Section Number	Command Line Option	Function
2.2.1	Target CPU specifications	
	–CPU	Specifies target CPU
2.2.2	Object module specifications	
	–[NO]OBJECT	Controls output of object module
	–[NO]DEBUG	Controls output of debugging information
	–ENDIAN	Selects big endian or little endian
2.2.3	Assembly listing specifications	
	–[NO]LIST	Controls output of assembly listing
	–[NO]SOURCE	Controls output of source program listing
	–[NO]CROSS_REFERENCE	Controls output of cross-reference listing
	–[NO]SECTION	Controls output of section information listing
	–[NO]SHOW	Controls output of part of source program listing
	–LINES	Specifies the number of lines in assemble listing
	–COLUMNS	Specifies the number of columns in assemble listing
2.2.4	File inclusion function specifications	
	–INCLUDE	Specifies the include file directory
2.2.5	Conditional assembly specifications	
	–ASSIGNA	Defines integer preprocessor variable
	–ASSIGNC	Defines character preprocessor variable
	–DEFINE	Defines replacement character string
2.2.6	Assembler execution specifications	
	–EXPAND	Outputs preprocessor expansion result
	–ABORT	Changes the error level at which the assembler is abnormally terminated

Table 2-1 Command Line Options (cont)

Section Number	Command Line Option	Function
2.2.7	Japanese character description specifications	
	–SJIS	Interprets Japanese characters in source file as shift JIS code
	–EUC	Interprets Japanese characters in source file as EUC code
	–OUTCODE	Specifies the Japanese code for output to object code
2.2.8	Automatic literal pool generation specifications	
	–AUTO_LITERAL	Specifies size mode for automatic literal pool generation
2.2.9	Command line specifications	
	–SUBCOMMAND	Inputs command line from a file
2.2.10	Floating-point data specifications	
	–ROUND	Specifies the rounding mode for floating-point data
	–DENORMALIZE	Specifies how to handle denormalized numbers in floating-point data

Supplement:

The assemble listing is a listing to which the results of the assembly processing are output, and consists of a source program listing, a cross-reference listing, and a section information listing.

References: See appendix C, "Assemble Listing Example", for a detailed description of the assemble listing.

2.2 Command Line Option Reference

2.2.1 Target CPU Command Line Option

This assembler provides the following command line option concerned with the target CPU.

-CPU

This command line option specifies the target CPU.

```
-CPU
```

Target CPU Specification

Syntax

```
-CPU=<target CPU>
```

Description

1. The –CPU option specifies the target CPU for the source program to be assembled.

2. The following CPUs can be specified.

   - SH1 (for SH-1)
   - SH2 (for SH-2)
   - SH2E (for SH-2E)
   - SH3 (for SH-3)
   - SH3E (for SH-3E)
   - SH4 (for SH-4)
   - SHDSP (for SH-DSP)
   - SH3DSP (for SH3-DSP)

Relationship with Assembler Directives

Command Line Option	Assembler Directive	SHCPU Environment Variable	Result
–CPU	(regardless of any specification)	(regardless of any specification)	Target CPU specified by –CPU
(no specification)	.CPU <target CPU>	(regardless of any specification)	Target CPU specified by .CPU
	(no specification)	SHCPU = <target CPU>	Target CPU specified by SHCPU environment variable
		(no specification)	SH1

References: Target CPU
→ Programmer's Guide, 5.2.1, "Target CPU Assembler Directive," .CPU

SHCPU environment variable
→ User's Guide, 1.3, "SHCPU Environment Variable"

2.2.2 Object Module Command Line Options

This assembler provides the following command line options concerned with object modules.

-OBJECT	-NOOBJECT

These command line options control output of an object module.

-DEBUG	-NODEBUG

These command line options control output of debug information.

-ENDIAN

This command line option selects big endian or little endian.

-OBJECT	-NOOBJECT

Object Module Output Control

Syntax

```
-OBJECT [= <object output file>]
-NOOBJECT
```

The abbreviated forms are indicated by bold face.

Description

1. The –OBJECT option specifies output of an object module.

   The –NOOBJECT option specifies no output of an object module.

2. The object output file specifies the output destination for the object module.

3. When the object output file parameter is omitted, the assembler takes the following actions:

   — If the file format is omitted:
   The file format "obj" is supplied.

   — If the specification is completely omitted:
   The file format "obj" is appended to the name of the input source file (the first specified source file).

CAUTION!

Do not specify the same file for the input source file and the output object file. If the same file is specified, the contents of the input source file will be lost.

Relationship with Assembler Directives

The assembler gives priority to specifications made with command line options.

Command Line Option	Assembler Directive	Result
–OBJECT	(regardless of any specification)	An object module is output.
–NOOBJECT	(regardless of any specification)	An object module is not output.
(no specification)	.OUTPUT OBJ	An object module is output.
	.OUTPUT NOOBJ	An object module is not output.
	(no specification)	An object module is output.

-DEBUG	-NODEBUG

Debug Information Output Control

Syntax

```
-DEBUG
-NODEBUG
```

The abbreviated forms are indicated by bold face.

Description

1. The –DEBUG option specifies output of debug information.

   The –NODEBUG option specifies no output of debug information.

2. The –DEBUG and –NODEBUG options are only valid in cases where an object module is being output.

3. To output debug information, the assembler automatically generates a directory with the name "dwfinf" under the directory to which the object file is output, and outputs a supplement debugging information (ELF/DWARF supplement information) file whose file name is the same as the object file and whose file format is "dwi".

   References: Object module output
   → Programmer's Guide, 5.2.6, "Object Module Assembler Directives", .OUTPUT
   → User's Guide, 2.2.2, "Object Module Command Line Options", –OBJECT –NOOBJECT

Relationship with Assembler Directives

The assembler gives priority to specifications made with command line options.

Command Line Option	Assembler Directive	Result
–DEBUG	(regardless of any specification)	Debug information is output.
–NODEBUG	(regardless of any specification)	Debug information is not output.
(no specification)	.OUTPUT DBG	Debug information is output.
	.OUTPUT NODBG	Debug information is not output.
	(no specification)	Debug information is not output.

-DEBUG	-NODEBUG

Supplement:

Debug information is required when debugging a program using the debugger or the emulator, and is part of the object module. Debug information includes information about source statement lines and information about symbols.

-ENDIAN

Big Endian or Little Endian Selection

Syntax

```
-ENDIAN[=<endian>]

Endian:{BIG|LITTLE}
```

The abbreviated form is indicated by bold face.

Description

1. The –ENDIAN option selects big endian or little endian for the target CPU.
2. The default is big endian.

Relationship with Assembler Directives

The assembler gives priority to specifications made with command line options.

Command Line Option	Assembler Directive	Result
–ENDIAN=BIG	(regardless of any specification)	Assembles in big endian
–ENDIAN=LITTLE	(regardless of any specification)	Assembles in little endian
(no specification)	.ENDIAN BIG	Assembles in big endian
	.ENDIAN LITTLE	Assembles in little endian
	(no specification)	Assembles in big endian

Reference: .ENDIAN
→ Programmer's Guide, 5.2.6, "Object Module Assembler Directives," .ENDIAN

2.2.3 Assembly Listing Command Line Options

This assembler provides the following command line options concerned with the assemble listing.

`-LIST` `-NOLIST`

These command line options control output of an assemble listing.

`-SOURCE` `-NOSOURCE`

These command line options control output of a source program listing.

`-CROSS_REFERENCE` `-NOCROSS_REFERENCE`

These command line options control output of a cross-reference listing.

`-SECTION` `-NOSECTION`

These command line options control output of a section information listing.

`-SHOW` `-NOSHOW`

These command line options control output of the source program listing.

`-LINES`

This command line option sets the number of lines in the assemble listing.

`-COLUMNS`

This command line option sets the number of columns in the assemble listing.

-LIST	-NOLIST

Assemble Listing Output Control

Syntax

```
-LIST [ =<listing output file> ]
-NOLIST
```

The abbreviated forms are indicated by bold face.

Description

1. The –LIST option specifies output of an assemble listing.

   The –NOLIST option specifies no output of an assemble listing.

2. The listing output file specifies the output destination file for the assemble listing.

3. When the listing output file parameter is omitted, the assembler takes the following actions:

   — If the file format is omitted:
   The file format "lis" is supplied.

   — If the specification is completely omitted:
   The file format "lis" is appended to the name of the input source file (the first specified source file).

CAUTION!

Do not specify the same file for the input source file and the output object file. If the same file is specified, the contents of the input source file will be lost.

Relationship with Assembler Directives

The assembler gives priority to specifications made with command line options.

Command Line Option	Assembler Directive	Result
–LIST	(regardless of any specification)	An assemble listing is output.
–NOLIST	(regardless of any specification)	An assemble listing is not output.
(no specification)	.PRINT LIST	An assemble listing is output.
	.PRINT NOLIST	An assemble listing is not output.
	(no specification)	An assemble listing is not output.

-SOURCE	-NOSOURCE

Source Program Listing Output Control

Syntax

```
-SOURCE
-NOSOURCE
```

The abbreviated forms are indicated by bold face.

Description

1. The –SOURCE option specifies output of a source program listing to the assemble listing.

   The –NOSOURCE option specifies no output of a source program listing to the assemble listing.

2. The –SOURCE and –NOSOURCE options are only valid in cases where an assemble listing is being output.

   References: Assemble listing output
   → Programmer's Guide, 5.2.7, "Assemble Listing Assembler Directives", .PRINT
   → User's Guide, 2.2.3, "Assemble Listing Command Line Options", –LIST –NOLIST

Relationship with Assembler Directives

The assembler gives priority to specifications made with command line options.

Command Line Option	Assembler Directive	Result (When an Assemble Listing Is Output)
–SOURCE	(regardless of any specification)	A source program listing is output.
–NOSOURCE	(regardless of any specification)	A source program listing is not output.
(no specification)	.PRINT SRC	A source program listing is output.
	.PRINT NOSRC	A source program listing is not output.
	(no specification)	A source program listing is output.

-CROSS_REFERENCE	-NOCROSS_REFERENCE

Cross-Reference Listing Output Control

Syntax

```
-CROSS_REFERENCE
-NOCROSS_REFERENCE
```

The abbreviated forms are indicated by bold face.

Description

1. The –CROSS_REFERENCE option specifies output of a cross-reference listing to the assemble listing.

   The –NOCROSS_REFERENCE option specifies no output of a cross-reference listing to the assemble listing.

2. The –CROSS_REFERENCE and –NOCROSS_REFERENCE options are only valid in cases where an assemble listing is being output.

   References: Assemble listing output
   → Programmer's Guide, 5.2.7, "Assemble Listing Assembler Directives", .PRINT
   → User's Guide, 2.2.3, "Assemble Listing Command Line Options", –LIST –NOLIST

Relationship with Assembler Directives

The assembler gives priority to specifications made with command line options.

Command Line Option	Assembler Directive	Result (When an Assemble Listing Is Output)
–CROSS_REFERENCE	(regardless of any specification)	A cross-reference listing is output.
–NOCROSS_REFERENCE	(regardless of any specification)	A cross-reference listing is not output.
(no specification)	.PRINT CREF	A cross-reference listing is output.
	.PRINT NOCREF	A cross-reference listing is not output.
	(no specification)	A cross-reference listing is output.

-SECTION	-NOSECTION

Section Information Listing Output Control

Syntax

```
-SECTION
-NOSECTION
```

The abbreviated forms are indicated by bold face.

Description

1. The –SECTION option specifies output of a section information listing to the assemble listing.

   The –NOSECTION option specifies no output of a section information listing to the assemble listing.

2. The –SECTION and –NOSECTION options are only valid in cases where an assemble listing is being output.

   References: Assemble listing output
   → Programmer's Guide, 5.2.7, "Assemble Listing Assembler Directives", .PRINT
   → User's Guide, 2.2.3, "Assemble Listing Command Line Options", –LIST –NOLIST

Relationship with Assembler Directives

The assembler gives priority to specifications made with command line options.

Command Line Option	Assembler Directive	Result (When an Assemble Listing Is Output)
–SECTION	(regardless of any specification)	A section information listing is output.
–NOSECTION	(regardless of any specification)	A section information listing is not output.
(no specification)	.PRINT SCT	A section information listing is output.
	.PRINT NOSCT	A section information listing is not output.
	(no specification)	A section information listing is output.

-SHOW	-NOSHOW

Source Program Listing Output Control

Syntax

```
<UNIX>
-SHOW [= <output type>[,<output type> ...]]
-NOSHOW [= <output type>[,<output type> ...]]

<Windows®95 and Windows®NT>
-SHOW [=(<output type>[,<output type> ...])]
-NOSHOW [=(<output type>[,<output type> ...])]
```

When only one output type is specified, the parentheses can be omitted.

```
Output type:   {CONDITIONALS|DEFINITIONS|CALLS|EXPANSIONS|CODE}
```

The abbreviated forms are indicated by bold face.

Description

1. The –SHOW option specifies output of preprocessor function source statements and object code lines in the source program listing.

   The –NOSHOW option suppresses output of specified preprocessor function source statements and object code display lines in the source program listing.

2. The items specified by output types will be output or suppressed depending on the option. When no output type is specified, all items will be output or suppressed.

   –SHOW: Output
   –NOSHOW: No output (suppress)

-SHOW	-NOSHOW

3. The following output types can be specified:

Output Type	Object	Description
CONDITIONALS	Failed condition	Condition-failed .AIF or .AIFDEF statements
DEFINITIONS	Definition	Macro definition parts, .AREPEAT and .AWHILE definition parts, .INCLUDE directive statements .ASSIGNA and .ASSSIGNC directive statements
CALLS	Call	Macro call statements, .AIF, .AIFDEF, and .AENDI directive statements
EXPANSIONS	Expansion	Macro expansion statements .AREPEAT and .AWHILE expansion statements
CODE	Object code lines	The object code lines exceeding the source statement lines

References: Source program listing output

→ Programmer's Guide, 5.2.7, "Assemble Listing Assembler Directives", .PRINT

→ User's Guide, 2.2.3, "Assemble Listing Command Line Options", –LIST –NOLIST –SOURCE –NOSOURCE

Relationship with Assembler Directives

The assembler gives priority to specifications made with command line options.

Command Line Option	Assembler Directive	Result
–SHOW=<output type>	(regardless of any specification)	The object code is output.
–NOSHOW=<output type>	(regardless of any specification)	The object code is not output.
(no specification)	.LIST <output type> (output)	The object code is output.
	.LIST <output type> (suppress)	The object code is not output.
	(no specification)	The object code is output.

-LINES

Setting of the Number of Lines in the Assemble Listing

Syntax

```
-LINES=<line count>
```

The abbreviated form is indicated by bold face.

Description

1. The –LINES option sets the number of lines on a single page of the assemble listing. The range of valid values for the line count is from 20 to 255.

2. The –LINES option is only valid in cases where an assemble listing is being output.

   References: Assemble listing output
   → Programmer's Guide, 5.2.7, "Assemble Listing Assembler Directives", .PRINT
   → User's Guide, 2.2.3, "Assemble Listing Command Line Options", –LIST –NOLIST

Relationship with Assembler Directives

The assembler gives priority to specifications made with command line options.

Command Line Option	Assembler Directive	Result
–LINES=<line count>	(regardless of any specification)	The number of lines on a page is given by –LINES.
(no specification)	.FORM LIN=<line count>	The number of lines on a page is given by .FORM.
	(no specification)	The number of lines on a page is 60 lines.

Setting of the Number of Columns in the Assemble Listing

Syntax

```
-COLUMNS=<column count>
```

The abbreviated form is indicated by bold face.

Description

1. The –COLUMNS option sets the number of columns in a single line of the assemble listing. The range of valid values for the column count is from 79 to 255.

2. The –COLUMNS option is only valid in cases where an assemble listing is being output.

   References: Assemble listing output
   → Programmer's Guide, 5.2.7, "Assemble Listing Assembler Directives", .PRINT
   → User's Guide, 2.2.3, "Assemble Listing Command Line Options", –LIST –NOLIST

Relationship with Assembler Directives

The assembler gives priority to specifications made with command line options.

Command Line Option	Assembler Directive	Result
–COLUMNS= <column count>	(regardless of any specification)	The number of columns in a line is given by –COLUMNS.
(no specification)	.FORM COL=<column count>	The number of columns in a line is given by .FORM.
	(no specification)	The number of columns in a line is 132 columns.

2.2.4 File Inclusion Function Command Line Option

This assembler provides the following command line option concerned with the file inclusion function.

-INCLUDE

This command line option specifies the include file directory.

Include File Directory Specification

Syntax

```
-INCLUDE=<directory name>[,<directory name...]
```

The abbreviated form is indicated by bold face.

Description

1. The –INCLUDE option specifies the include file directory.
2. The directory name depends on the naming rule of the host machine used.
3. As many directory name as can be input in one command line can be specified.
4. The current directory is searched, and then the directories specified by the –INCLUDE are searched in the specified order.

Relationship with Assembler Directives

Command Line Option	Assembler Directive	Result
–INCLUDE	(regardless of any specification)	(1) Directory specified by .INCLUDE
		(2) Directory specified by –INCLUDE*
(no specification)	.INCLUDE <file name>	Directory specified by .INCLUDE

Note: The directory specified by the –INCLUDE option is added before that specified by .INCLUDE.

Note

`asmsh aaa.mar -include=/usr/tmp,/tmp` (UNIX)

(.INCLUDE "file.h" is specified in aaa.mar.)

The current directory, /usr/tmp, and /tmp are searched for file.h in that order.

Reference: .INCLUDE
→ Programmer's Guide, 6, "File Inclusion Function"

2.2.5 Conditional Assembly Command Line Options

This assembler provides the following command line options concerned with conditional assembly.

-ASSIGNA

This command line option defines integer preprocessor variable.

-ASSIGNC

This command line option defines character preprocessor variable.

-DEFINE

This command line option defines replacement character string.

Integer Preprocessor Variable Definition

Syntax

```
-ASSIGNA=<preprocessor variable>=<integer constant>
                [,<preprocessor variable>=<integer constant>...]
```

The abbreviated form is indicated by bold face.

Description

1. The –ASSIGNA option sets an integer constant to a preprocessor variable.
2. The naming rule of preprocessor variables is the same as that of symbols.
3. An integer constant is specified by combining the radix (B', Q', D', or H') and a value. If the radix is omitted, the value is assumed to be decimal.
4. An integer constant must be within the range from –2,147,483,648 to 4,294,967,295. To specify a negative value, use a radix other than decimal.

Relationship with Assembler Directives

Command Line Option	Assembler Directive	Result
–ASSIGNA	.ASSIGNA*	Value specified by –ASSIGNA
	(no specification)	Value specified by –ASSIGNA
(no specification)	.ASSIGNA	Value specified by .ASSIGNA

Note: When a value is assigned to a preprocessor variable by the –ASSIGNA option, the definition of the preprocessor variable by .ASSIGNA is invalidated.

Note

When the host machine uses UNIX as the OS, specify a backslash (\) before the apostrophe (') of the radix. If a preprocessor variable includes a dollar mark ($), specify a backslash (\) before the dollar mark.

Example: `asmsh aaa.mar -assigna=_\$=H\'FF` (UNIX)

Value H'FF is assigned to preprocessor variable _$. All references (\&_$) to preprocessor variable _$ in the source program are set to H'FF.

-ASSIGNA

Reference: .ASSIGNA
→ Programmer's Guide, 7.2, "Conditional Assembly Directive," .ASSIGNA

Character Preprocessor Variable Definition

Syntax

```
-ASSIGNC=<preprocessor variable>="<character string>"
                   [,<preprocessor variable>="<character
string>"...]
```

The abbreviated form is indicated by bold face.

Description

1. The –ASSIGNC option sets a character string to a preprocessor variable.
2. The naming rule of preprocessor variables is the same as that of symbols.
3. A character string must be enclosed with double-quotation marks (").
4. Up to 255 characters (bytes) can be specified for a character string.

Relationship with Assembler Directives

Command Line Option	Assembler Directive	Result
–ASSIGNC	.ASSIGNC directive*	Character string specified by –ASSIGNC
	(no specification)	Character string specified by –ASSIGNC
(no specification)	.ASSIGNC directive	Character string specified by .ASSIGNC

Note: When a character string is assigned to a preprocessor variable by the –ASSIGNC option, the definition of the preprocessor variable by .ASSIGNC is invalidated.

Note

To specify the following characters in a character string when the host machine uses UNIX as the OS, specify a backslash (\) before the characters. To specify character strings before and after the following characters, enclose the character strings with double-quotation marks (").

- Exclamation mark (!)
- Double-quotation mark (")
- Dollar mark ($)
- Back quotation mark (`)

-ASSIGNC

```
asmsh aaa.mar -assignc=_\$="ON"\!"OFF"
```
(UNIX)

Character string ON!OFF is assigned to preprocessor variable _$. All references (\&_$) to preprocessor variable _$ in the source program are set to ON!OFF.

Reference: .ASSIGNC
→ Programmer's Guide, 7.2, "Conditional Assembly Directive," .ASSIGNC

Replacement Character String Definition

Syntax

```
-DEFINE=<replacement symbol>="<character string>"
                    [,<replacement symbol>="<character
string>"...]
```

The abbreviated form is indicated by bold face.

Description

1. The –DEFINE option defines that the specified symbol is replaced with the corresponding character string by the preprocessor.
2. Differences between –DEFINE and –ASSIGNC are the same as those between .DEFINE and .ASSIGNC.

Relationship with Assembler Directives

Command Line Option	Assembler Directive	Result
–DEFINE	.DEFINE directive*	Character string specified by –DEFINE
	(no specification)	Character string specified by –DEFINE
(no specification)	.DEFINE directive	Character string specified by .DEFINE

Note: When a character string is assigned to a replacement symbol by the –DEFINE option, the definition of the replacement symbol by .DEFINE is invalidated.

Reference: .DEFINE
→ Programmer's Guide, 7.2, "Conditional Assembly Directive," .DEFINE

2.2.6 Assembler Execution Command Line Option

This assembler provides the following command line options concerned with assembler execution.

-EXPAND

This command line option outputs preprocessor expansion result.

-ABORT

This command line option changes the error level at which the assembler is abnormally terminated.

Preprocessor Expansion Result Output

Syntax

```
-EXPAND[=<output file name>]
```

The abbreviated form is indicated by bold face.

Description

1. The –EXPAND option outputs an assembler source file for which macro expansion, conditional assembly, and file inclusion have been performed.

2. When this option is specified, no object will be generated.

3. When the output file parameter is omitted, the assembler takes the following actions:

   — If the file format is omitted:
   The file format "exp" is used.

   — If the specification is completely omitted:
   The file format "exp" is appended to the name of the input source file (the first specified source file).

4. Do not specify the same file name for the input and output files.

-ABORT

Change of Error Level at Which the Assembler Is Abnormally Terminated

Syntax

```
-ABORT=<error level>

Error level:{WARNING|ERROR}
```

The abbreviated form is indicated by bold face.

Description

1. The –ABORT option specifies the error level and changes the return value to the OS depending on the assembly result.

2. The return value to the OS is as follows:

Number of Cases			Return Value to OS when Option Specified			
			ABORT=WARNING		ABORT=ERROR*	
Warning	Error	Fatal Error	Windows®95, Windows®NT	UNIX	Windows®95, Windows®NT	UNIX
0	0	0	0	0	0	0
1 or more	0	0	2	1	0	0
—	1 or more	0	2	1	2	1
—	—	1 or more	4	1	4	1

Note: The underline indicates the default option setting.

3. When the return value to the OS becomes 1 or larger, the object module is not output.

4. The –ABORT option is valid only when the object module output is specified.

2.2.7 Japanese Character Description Command Line Options

This assembler provides the following command line options concerned with Japanese characters description in source files.

```
-SJIS
```

This command line option interprets Japanese kanji characters in source files as shift JIS code.

```
-EUC
```

This command line option interprets Japanese kanji characters in source files as EUC code.

```
-OUTCODE
```

This command line option specifies the Japanese kanji code for output to object file.

-SJIS

Interpretation of Japanese Characters as Shift JIS Code

Syntax

```
-SJIS
```

Description

1. The –SJIS option enables Japanese characters to be written in character strings and comments.

   SJIS .... Japanese characters in character strings and comments are interpreted as shift JIS code.

   No specification .... Japanese characters in character strings and comments are interpreted as Japanese code specified by the host machine.

2. Do not specify this option together with the –EUC option.

Reference: Shift JIS code
→ Programmer's Guide, 1.4.2 "Character Constants"

Interpretation of Japanese Characters as EUC Code

Syntax

```
-EUC
```

Description

1. The –EUC option enables Japanese characters to be written in character strings and comments.

   EUC.............................Japanese characters in character strings and comments are interpreted EUC code.

   No specification ....Japanese characters in character strings and comments are interpreted as Japanese code specified by the host machine.

2. Do not specify this option together with the –SJIS option.

Reference: EUC code
→ Programmer's Guide, 1.4.2 "Character Constants"

`-OUTCODE`

Specification of Japanese Code for Output to Object File

Syntax

```
-OUTCODE=<Japanese code>
<Japanese code>:{SJIS|EUC}
```

The abbreviated form is indicated by bold face.

Description

1. The –OUTCODE option converts Japanese characters in the source file to the specified Japanese kanji code for output to the object file.

2. The Japanese code output to the object file depends on the –OUTCODE specification and the code (–SJIS or –EUC) in the source file as follows:

–OUTCODE Specification	Japanese Code in Source File		
	–SJIS	**–EUC**	**No Specification**
SJIS	Shift JIS code	Shift JIS code	Shift JIS code
EUC	EUC code	EUC code	EUC code
No specification	Shift JIS code	EUC code	Default code

Default code is as follows.

Host Machine	Default Code
SPARC station	EUC code
HP9000/700 series	Shift JIS code
PC9800 series IBM PC and its compatible machine	Shift JIS code

Reference: Japanese code in the source file
→ User's Guide, 2.2.7 "Japanese Character Description Command Line Options" –SJIS
→ User's Guide, 2.2.7 "Japanese Character Description Command Line Options" –EUC

2.2.8 Automatic Literal Pool Generation Command Line Option

This assembler provides the following command line option concerned with automatic literal pool generation.

```
-AUTO_LITERAL
```

This command line option specifies the size mode for automatic literal pool generation.

-AUTO_LITERAL

Size Mode Specification for Automatic Literal Pool Generation

Syntax

```
-AUTO_LITERAL
```

The abbreviated form is indicated by bold face.

Description

1. The –AUTO_LITERAL option specifies the size mode for automatic literal pool generation.

   — When this command line option is specified, automatic literal pool generation is performed in size selection mode, and the assembler checks the imm value in the data move instruction without operation size specification (MOV #imm,Rn) and automatically generates a literal pool if necessary.

   — When this option is not specified, automatic literal pool generation is performed in size specification mode, and the data move instruction without size specification is handled as a 1-byte data move instruction.

2. In the size selection mode, the imm value in the data move instruction without operation size specification is handled as a signed value. Therefore, a value within the range from H'00000080 to H'000000FF (128 to 255) is regarded as word-size data.

	Selected Size or Error	
imm Value Range*	**Size Selection Mode**	**Size Specification Mode**
H'80000000 to H'FFFF7FFF (–2,147,483,648 to –32,769)	Long word	Warning 835
H'FFFF8000 to H'FFFFFF7F (–32,768 to –129)	Word	Warning 835
H'FFFFFF80 to H'0000007F (–128 to 127)	Byte	Byte
H'00000080 to H'000000FF (128 to 255)	Word	Byte
H'00000100 to H'00007FFF (256 to 32,767)	Word	Warning 835
H'00008000 to H'7FFFFFFF (32,768 to 2,147,483,647)	Long word	Warning 835

Note: The value in parentheses ( ) is in decimal.

Reference: Size selection mode
Size specification mode
→ Programmer's Guide, 9.3 "Size Mode for Automatic Literal Pool Generation"

2.2.9 Command Line Input Command Line Option

This assembler provides the following command line option concerned with command line input.

```
-SUBCOMMAND
```

This command line option inputs command line specifications from a file.

Command Line Specification Input from File

Syntax

```
-SUBCOMMAND=<subcommand file name>
```

The abbreviated form is indicated by bold face.

Description

1. The –SUBCOMMAND option inputs command line specifications from a file.
2. Specify input file names and command line options in the subcommand file in the same order as for normal command line specifications.
3. Only one input file name or one command line option can be specified in one line in the subcommand file.
4. This option must be specified at the end of a command line. The remaining files and options are read from the specified subcommand file.
5. This option must not be specified in a subcommand file.

Example:

```
asmsh aaa.src -subcommand=aaa.sub
```

The subcommand file contents are expanded to a command line and assembled.

```
--------aaa.sub contents --------
        bbb.src
        -list
        -noobj
```

The above command line and file aaa.sub are expanded as follows:

```
asmsh aaa.src,bbb.src -list -noobj
```

`-SUBCOMMAND`

Notes

1. One line of a subcommand file can include a maximum of 300 bytes.

2. One subcommand file can include a maximum of 32,767 bytes.

2.2.10 Floating-Point Data Command Line Options

This assembler provides the following command line options concerned with floating-point data.

-ROUND

This command line option specifies the rounding mode for floating-point data.

-DENORMALIZE

This command line option specifies how to handle denormalized numbers in floating-point data.

-ROUND

Specification of Floating-Point Data Rounding Mode

Syntax

```
-ROUND=<rounding mode>
<rounding mode>:{NEAREST|ZERO}
```

The abbreviated form is indicated by bold face.

Description

1. The –ROUND option specifies the rounding mode used when converting constants in floating-point data assembler directives into object codes.

2. The following two rounding modes can be selected.

   — round to NEAREST even (NEAREST)
   — round to ZERO (ZERO)

3. When the –ROUND option is not specified, the rounding mode depends on the CPU type as follows:

CPU Type	Rounding Mode
SH-1	round to NEAREST even
SH-2	round to NEAREST even
SH-2E	round to ZERO
SH-3	round to NEAREST even
SH-3E	round to ZERO
SH-4	round to NEAREST even
SH-DSP	round to NEAREST even
SH3-DSP	round to NEAREST even

CAUTION!

When the CPU type is SH-2E or SH-3E and round to NEAREST even is selected as the rounding mode, warning number 818 occurs at the first floating-point data assembler directive in the source program, and object code is output in the selected "round to NEAREST even" rounding mode.

Reference: Rounding mode
→ Programmer's Guide, 1.4.3 "Floating-Point Constants"

```
-DENORMALIZE
```

Specification of Handling Denormalized Numbers in Floating-Point Data

Syntax

```
-DENORMALIZE=<selection type>
<selection type>:{ON|OFF}
```

The abbreviated form is indicated by bold face.

Description

1. The –DENORMALIZE option specifies whether to handle the denormalized numbers in floating-point data assembler directives as valid values.

2. The object code differs when denormalized numbers are specified as valid values (ON) and invalid values (OFF).

   — Valid: Warning number 842 occurs and the object code is output.
   — Invalid: Warning number 841 occurs and zero is output for the object code.

3. When the –DENORMALIZE option is not specified, whether the denormalized numbers are valid depends on the CPU type as follows:

CPU Type	Denormalized Numbers
SH-1	Valid (ON)
SH-2	Valid (ON)
SH-2E	Invalid (OFF)
SH-3	Valid (ON)
SH-3E	Invalid (OFF)
SH-4	Valid (ON)
SH-DSP	Valid (ON)
SH3-DSP	Valid (ON)

CAUTION!

When the CPU type is SH-2E or SH-3E and denormalized numbers are specified as valid, warning number 818 occurs at the first floating-point data assembler directive in the source program, and object code is output with the denormalized numbers handled as valid values as specified.

Reference: Denormalized numbers
→ Programmer's Guide, 1.4.3 "Floating-Point Constants"

Appendix

Appendix A Limitations and Notes on Programming

Table A-1 Limitations and Notes on Programming

No.	Item	Limitation	
1	Character types	ASCII characters, shift JIS code, EUC code	
2	Upper/lowercase letter distinction	Symbols (including section names) Object module names	Distinguished
		Reserved words Executable instruction mnemonics DSP instruction mnemonics Assembler directive mnemonics Operation sizes Integer constant radixes	Not distinguished
3	Line length	Up to 255 bytes	
4	Program length (in lines)	Up to 65,535 lines	
5	Character constants	Up to 4 characters	
6	Symbol length	Up to 251 characters	
7	Number of symbols	Up to 65,535 symbols	
8	Number of import symbols	Up to 65,535 symbols	
9	Number of export symbols	Up to 65,535 symbols	
10	Section size	Up to H'FFFFFFFF bytes	
11	Number of sections	Up to 65,535 sections	
12	Number of macro generation numbers	Up to 100,000 numbers	
13	Number of literals	Up to 100,000 literals	

Appendix B Sample Program

This appendix presents a sample program written for this assembler.

B.1 Sample Program Specifications

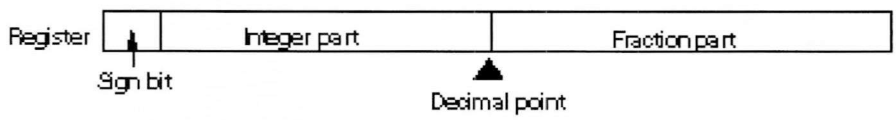
Functional Specification

Macros and subroutines for addition, subtraction, multiplication, and division of fixed-point data in the following format:

<parameter 1> OP <parameter 2> → result
OP: +, –, ×, ÷

Note: Operation results are rounded off. Neither underflow nor overflow is checked.

Data Format



The location of the decimal point is set in preprocessor variable POINT as the number of bits from the MSB.

Inputs and Outputs

Inputs: Set parameter 1 in register Parm1.
Set parameter 2 in register Parm2.
For addition and subtraction, parameters 1 and 2 can be specified as macro parameters.
Output: The result is stored in register Parm1.

Macro and Subroutine Usage

Addition (+): Macro call FIX_ADD [parameter 1], [parameter 2]
Subtraction (–): Macro call FIX_SUB [parameter 1], [parameter 2]
Multiplication (×): Subroutine call FIX_MUL
Division(÷): Subroutine call FIX_DIV

Registers to be Used

Define the following registers with the .REG directive:
Parm1, Parm2, WORK1, WORK2, WORK3, WORK4

B.2 Coding Example

```
         .MACRO   FIX ADD Rs=Parm2, Rd=Parm1
         ADD      \Rs,\Rd
         .ENDM

         .MACRO   FIX SUB Rs=Parm2,Rd=Parm1
         SUB      \Rs,\Rd
         .ENDM

FIX MUL:
         DIV0S    Parm1,Parm2            ;
         MOVT     WORK1                  ; Stores the sign of the result in WORK1.
         CMP/PZ   Parm1                  ;
         BT       MUL01                  ; If (Parm1 < 0), Parm1 = -Parm1
         NEG      Parm1,Parm1            ;
MUL01    CMP/PZ   Parm2                  ;
         BT       MUL02                  ; If (Parm2 < 0), Parm2 = -Parm2
         NEG      Parm2,Parm2            ;
MUL02    MULU     Parm1,Parm2            ; Parm1 (low) * Parm2 (low)
         SWAP.W   Parm1,Parm1            ;
         STS      MACL,WORK2             ;
         MULU     Parm1,Parm2            ; Parm1 (high) * Parm2 (low)
         SWAP.W   Parm1,Parm1            ;
         SWAP.W   Parm2,Parm2            ;
         STS      MACL,WORK3             ;
         MULU     Parm1,Parm2            ; Parm1 (low) * Parm2 (high)
         SWAP.W   Parm1,Parm1            ;
         STS      MACL,WORK4             ;
         MULU     Parm1,Parm2            ; Parm1 (high) * Parm2 (high)
         CLRT                            ;
         STS      MACL,Parm1             ;
         MOV      WORK3,Parm2            ;
         SHLR16   WORK3                  ;
         SHLL16   Parm2                  ;
         ADDC     Parm2,WORK2            ;
         ADDC     WORK3,Parm1            ; Sums 16-bit multiplication results.
         MOV      WORK4,Parm2            ;
         SHLR16   WORK4                  ;
         SHLL16   Parm2                  ;
         ADDC     WORK4,Parm1            ;
         .AREPEAT \&POINT                ;
         SHLL     Parm2                  ; Corrects decimal point location.
         ROTCL    Parm1                  ;
         .AENDR                          ;
         SHLR     WORK1                  ;
         BF       MUL03                  ; Adds the sign.
         NEG      Parm1,Parm1            ;
MUL03    RTS
         NOP
```

(Continued on following page.)

```
FIX_DIV:
        MOV      #0,WORK1          ;  If dividend is a negative value,
        DIV0S    WORK1,Parm1       ;  converts to 1's complement.
        SUBC     WORK1,Parm1       ;
        .AREPEAT \&POINT           ;  Corrects decimal point location.
        SHLR     Parm1             ;
        ROTCR    WORK1             ;
        .AENDR                     ;
        DIV0S    Parm2,Parm1       ;
        .AREPEAT 32                ;  Parm1:WORK1/Parm2 → WORK1
        ROTCL    WORK1             ;
        DIV1     Parm2,Parm1       ;
        .AENDR                     ;
        ROTCL    WORK1             ;
        MOV      #0,Parm1          ;  Converts to 2's complement.
        ADDC     Parm1,WORK1       ;
        MOV      WORK1,Parm1       ;
        RTS
        NOP
```

Appendix C Assemble Listing Output Example

The assemble listing shows the result of the assemble processing. The assemble listing consists of a source program listing, a cross-reference listing, and a section information listing.

This appendix describes the content and output format of the assemble listing using the assembly of the source program shown below as an example. This uses the sample program shown in appendix B to calculate the following:

$$1.5 \times 2.25 + 3 \div 5$$

```
POINT    .ASSIGNA 16
Parm1    .REG     (R0)
Parm2    .REG     (R1)
WORK1    .REG     (R2)
WORK2    .REG     (R3)
WORK3    .REG     (R4)
WORK4    .REG     (R5)

         .SECTION SAMPLE,CODE,ALIGN=4
         .INCLUDE "appendix B"

a        .REG     (R8)
b        .REG     (R9)
c        .REG     (R10)
d        .REG     (R11)

start
         STS      PR,@-SP
         MOV.L    #H'00018000,a
         MOV.L    #H'00024000,b
         MOV.L    #H'00030000,c
         MOV.L    #H'00050000,d

         MOV      a,Parm1
         MOV      b,Parm2
         BSR      FIX_MUL
         NOP
         MOV      Parm1,a
         MOV      c,Parm1
         MOV      d,Parm2
         BSR      FIX_DIV
         NOP
         FIX_ADD  a
         MOV      Parm1,a
         LDS      @SP+,PR
         RTS
         NOP
         .END
```

C.1 Source Program Listing

The source program listing lists information related to the source statements, including the line number and the corresponding object code.

Figure C-1 shows an example of a source program listing.

```
*** SuperH RISC engine ASSEMBLER Ver. 4.0 ***        01/12/95 19:52:40
PROGRAM NAME =                                      'SAMPLE'                (7)

    1                              1          .HEADING """SAMPLE"""
    2                              2   POINT  .ASSIGNA 16
    3                              3   Parm1  .REG    (R0)
    4                              4   Parm2  .REG    (R1)
    5                              5   WORK1  .REG    (R2)
    6                              6   WORK2  .REG    (R3)
    7                              7   WORK3  .REG    (R4)
    8                              8   WORK4  .REG    (R5)

   20  00000000                    9 I1 FIX_MUL:
   21  00000000 2107              10 I1         DIV0S   Parm1,Parm2      ;
   22  00000002 0229              11 I1         MOVT    WORK1            ;
   23  00000004 4011              12 I1         CMP/PZ  Parm1            ; --
   24  00000006 8900              13 I1         BT      MUL01            ;   | if (Parm1
   25  00000008 600B              14 I1         NEG     Parm1,Parm1      ; --
  (1)    (2)          (3)         (4) (5)               (6)

  237                                    ***** BEGIN-POOL *****
  238  00000180 A008                     BRA TO END-POOL
  239  00000182 0009                     NOP
  240  00000184 00018000                 DATA FOR SOURCE-LINE 217          (8)
  241  00000188 00024000                 DATA FOR SOURCE-LINE 218
  242  0000018C 00030000                 DATA FOR SOURCE-LINE 219
  243  00000190 00050000                 DATA FOR SOURCE-LINE 220
  244                                    ***** END-POOL *****
  245                             59          .END

  *****TOTAL ERRORS        0
  *****TOTAL WARNINGS      0
          (9)
```

Figure C-1 Source Program Listing Output Example

(1) Line numbers (in decimal)

(2) The value of the location counter (in hexadecimal)

(3) The object code (in hexadecimal). The size of the reserved area in bytes is listed for areas reserved with the .RES, .SRES, .SRESC, .SRESZ, and .FRES assembler directives.

(4) Source line numbers (in decimal)

(5) Expansion type. Whether the statement is expanded by file inclusion, conditional assembly function, or macro function is listed.

    In: File inclusion (n indicates the nest level).

    C: Satisfied conditional assembly, performed iterated expansion, or satisfied conditional iterated expansion

    M: Macro expansion

(6) The source statements

(7) The header setup with the .HEADING assembler directive.

(8) The literal pool

(9) The total number of errors and warnings. Error messages are listed on the line following the source statement that caused the error.

C.2 Cross-Reference Listing

The cross-reference listing lists information relating to symbols, including the attribute and the value.

Figure C-2 shows an example of a cross-reference listing.

```
*** SuperH RISC engine ASSEMBLER Ver. 4.0 ***        01/12/95 19:52:40

*** CROSS REFERENCE LIST

NAME                                SECTION  ATTR VALUE              SEQUENCE

FIX_DIV                             SAMPLE        00000058     94*    229
FIX_MUL                             SAMPLE        00000000     20*    224
MANOS                                        UDEF 00000000     39
MUL01                               SAMPLE        0000000A     24     26*
MUL02                               SAMPLE        00000010     27     29*
Parm1                                        REG                3*    21     23     25
                                                               37     37     39     41
                                                               69     71     73     75
                                                               95     97    102    104
                                                              122    124    126    128
                                                              150    152    154    156
                                                              174    176    178    180
                                                              198    200    202    204
Parm2                                        REG                4*    21     26     28
                                                               44     45     47     49
                                                               70     72     74     76
                                                              144    146    148    150
                                                              168    170    172    174
____________________________________ ________ ____ ________  ___________________________
       (1)                             (2)     (3)    (4)        (5)
```

Figure C-2 Cross-Reference Listing Output Example

(1) The symbol name

(2) The name of the section that includes the symbol (first eight characters)

(3) The symbol attribute

EXPT	Export symbol
IMPT	Import symbol
SCT	Section name
REG	Symbol defined with the .REG assembler directive
FREG	Symbol defined with the .FREG assembler directive
ASGN	Symbol defined with the .ASSIGN assembler directive
EQU	Symbol defined with the .EQU assembler directive
MDEF	Symbol defined two or more times
UDEF	Undefined symbol
No symbol attribute (blank)	A symbol other than those listed above

(4) The value of symbol (in hexadecimal)

(5) The list line numbers (in decimal) of the source statements where the symbol is defined or referenced. The line number marked with an asterisk is the line where the symbol is defined.

C.3 Section Information Listing

The section information listing lists information related to the sections in a program, including the section type and section size.

Figure C-3 shows an example of a section information listing.

```
*** SuperH RISC engine ASSEMBLER Ver. 4.0 ***        01/12/95 19:52:40

*** SECTION DATA LIST

SECTION                              ATTRIBUTE   SIZE         START

SAMPLE                               REL-CODE    00000194
 (1)                                    (2)        (3)          (4)
```

Figure C-3 Section Information Listing Output Example

(1) The section name

(2) The section type

REL .... Relative address section
ABS .... Absolute address section
CODE .... Code section
DATA .... Data section
COMMON .... Common section
STACK .... Stack section
DUMMY .... Dummy section

(3) The section size (in hexadecimal, byte units)

(4) The start address of absolute address sections

Appendix D Error Messages

D.1 Error Types

(1) Command Errors

These are errors related to the command line that starts the assembler. These errors can occur, for example, in cases where there are errors in the source file or command line option specifications.

The assembler outputs the error message to standard error output (usually the display).*1 The format of these messages is as follows:*2

```
" ", line <line number>:<error number> (E) <message>
```

Example:

```
" ", line 0: 10(E) NO INPUT FILE SPECIFIED
```

Notes: 1. The assembler outputs the message to standard output when Windows®95 or Windows®NT is used.

2. The format is as follows when Windows®95 or Windows®NT is used:

```
(<line number>): <error number>(E)<message>
```

Example:

```
(0): 10(E) NO INPUT FILE SPECIFIED
```

(2) Source Program Errors

These are syntax errors in the source program.

The assembler outputs the error message to standard output (usually the display) or the source program listing. (If a source program listing is output during assembly, these messages are not output to standard output.)*1

The format of these messages is as follows:*2

```
"<source file name>",line <line number>: <error number>(E)<message>
"<source file name>",line <line number>: <error number>(W)<message>
```

Example:

```
"PROG.SRC",line 25: 300(E) ILLEGAL MNEMONIC
"PROG.SRC",line 33: 811(W) ILLEGAL SYMBOL DEFINITION
```

Notes: 1. The assembler outputs the message to standard output or the source program listing when Windows®95 or Windows®NT is used.

2. The format is as follows when Windows®95 or Windows®NT is used:

```
<source file name>(<line number>): <error number>(E)<message>
<source file name>(<line number>): <error number>(W)<message>
```

Example:

```
PROG.SRC(25): 300(E) ILLEGAL MNEMONIC
PROG.SRC(33): 811(W) ILLEGAL SYMBOL DEFINITION
```

The source program error numbers are classified as follows:

100 to 199 .... General source program syntax errors
200 to 299 .... Errors in symbols
300 to 349 .... Errors in operations and/or operands
350 to 399 .... Errors in DSP instructions
400 to 499 .... Errors in expressions
500 to 599 .... Errors in assembler directives
600 to 699 .... Errors in file inclusion, conditional assembly, or macro function
700 to 799 .... Warnings in DSP instructions
800 to 999................. General source program warnings

(3) Fatal Errors

These are errors related to the assembler operating environment, and can occur, for example, if the available memory is insufficient.

The assembler outputs a message to standard error output.*1 The format of these messages is as follows:*2

```
" ", line <line number>:<error number> (F) <message>
```

Example:

```
" ", line 0: 903(F) LISTING FILE OUTPUT ERROR
```

Notes: 1. The assembler outputs the message to standard output when Windows®95 or Windows®NT is used.

2. The format is as follows when Windows®95 or Windows®NT is used:

```
(<line number>): <error number>(F)<message>
```

Example:

```
(0): 903(F) LISTING FILE OUTPUT ERROR
```

Assembly processing is interrupted when a fatal error occurs.

D.2 Error Message Tables

Table D-1 Command Error Messages

10	Message:	NO INPUT FILE SPECIFIED
	Meaning:	There is no input source file specified.
	Recovery procedure:	Specify an input source file.
20	Message:	CANNOT OPEN FILE <file name>
	Meaning:	The specified file cannot be opened.
	Recovery procedure:	Check and correct the file name and directory.
30	Message:	INVALID COMMAND PARAMETER
	Meaning:	The command line options are not correct.
	Recovery procedure:	Check and correct the command line options.
40	Message:	CANNOT ALLOCATE MEMORY
	Meaning:	All available memory is used up during processing.
	Recovery procedure:	This error only occurs when the amount of available user memory is extremely small. If there is other processing occurring at the same time as assembly, interrupt that processing and restart the assembler. If the error still occurs, check and correct the memory management employed on the host system.
50	Message:	COMPLETED FILE NAME TOO LONG <file name>
	Meaning:	The file name including the directory is too long.
	Recovery procedure:	Shorten the total length of the file name and directory path.
	Supplement:	It is possible that the object module output by the assembler after this error has occurred will not be usable with the debugger.

Table D-2 Source Program Error Messages

General Source Program Syntax Errors		
100	Message:	OPERATION TOO COMPLEX
	Error description:	Too complex operation.
	Recovery procedure:	Simplify the expression for the operation.
101	Message:	SYNTAX ERROR IN SOURCE STATEMENT
	Error description:	Syntax error in source statement.
	Recovery procedure:	Check and correct the whole source statement.
102	Message:	SYNTAX ERROR IN DIRECTIVE
	Error description:	Syntax error in assembler directive source statement.
	Recovery procedure:	Check and correct the whole source statement.
104	Message:	LOCATION COUNTER OVERFLOW
	Error description:	The value of location counter exceeded its maximum value.
	Recovery procedure:	Reduce the size of the program.
105	Message:	ILLEGAL INSTRUCTION IN STACK SECTION
	Error description:	An executable instruction, DSP instruction, extended instruction, or assembler directive that reserves data is in the stack section.
	Recovery procedure:	Remove, from the stack section, the executable instruction, DSP instruction, extended instruction, or assembler directive that reserves data.
106	Message:	TOO MANY ERRORS
	Error description:	Error display terminated due to too many errors.
	Recovery procedure:	Check and correct the whole source statement.
108	Message:	ILLEGAL CONTINUATION LINE
	Error description:	Illegal continuation line.
	Recovery procedure:	Check and correct continuation line.
109	Message:	LINE NUMBER OVERFLOW
	Error description:	The number of lines being assembled exceeded 65,535 lines.
	Recovery procedure:	Subdivide the program into multiple files.
150	Message:	INVALID DELAY SLOT INSTRUCTION
	Error description:	Illegal executable instruction placed following delayed branch instruction in memory.
	Recovery procedure:	Change the order of the instructions so that the illegal instruction does not immediately follow a delayed branch instruction.

Table D-2 Source Program Error Messages (cont)

151	Message:	ILLEGAL EXTENDED INSTRUCTION POSITION
	Error description:	Extended instruction placed following a delayed branch instruction in memory.
	Recovery procedure:	Place an executable instruction following the delayed branch instruction.
152	Message:	ILLEGAL BOUNDARY ALIGNMENT VALUE
	Error description:	Illegal boundary alignment value specified for a section including extended instructions.
	Recovery procedure:	Specify 2 or a larger multiple of 2 as a boundary alignment value.
153	Message:	ILLEGAL ADDRESS
	Error description:	Executable or extended instruction placed at an odd address.
	Recovery procedure:	Place executable and extended instructions at even addresses.
REPEAT Errors		
160	Message:	REPEAT LOOP NESTING
	Error description:	Another REPEAT is located between a REPEAT and its end address
	Recovery procedure:	Correct the REPEAT location.
161	Message:	ILLEGAL START ADDRESS FOR REPEAT LOOP
	Error description:	No executable or DSP instructions are located between a REPEAT and the start address.
	Recovery procedure:	Use one or more executable or DSP instructions between the REPEAT and the start address.
162	Message:	ILLEGAL DATA BEFORE REPEAT LOOP
	Error description:	Illegal data is found immediately before the loop specified by a REPEAT instruction.
	Recovery procedure:	If an assembler directive is located before the loop, correct the directive. If a literal pool is located before the loop, use a .NOPOOL directive to prevent the literal pool output.
	Supplement:	When three or fewer instructions are to be repeated, an executable or DSP instruction must be located before the loop.
Symbol Errors		
200	Message:	UNDEFINED SYMBOL REFERENCE
	Error description:	Undefined symbol reference.
	Recovery procedure:	Define the symbol.
201	Message:	ILLEGAL SYMBOL OR SECTION NAME
	Error description:	Reserved word specified as symbol (or section name).
	Recovery procedure:	Correct the symbol or section name.

Table D-2 Source Program Error Messages (cont)

202	Message:	ILLEGAL SYMBOL OR SECTION NAME
	Error description:	Illegal symbol (or section name).
	Recovery procedure:	Correct the symbol or section name.
203	Message:	ILLEGAL LOCAL LABEL
	Error description:	Illegal local label.
	Recovery procedure:	Correct the local label.
Operation and Operand Errors		
300	Message:	ILLEGAL MNEMONIC
	Error description:	Illegal operation.
	Recovery procedure:	Correct the operation.
301	Message:	TOO MANY OPERANDS OR ILLEGAL COMMENT
	Error description:	Too many operands of executable instruction, or illegal comment format.
	Recovery procedure:	Check and correct the operands and comment.
304	Message:	LACKING OPERANDS
	Error description:	Too few operands.
	Recovery procedure:	Correct the operands.
307	Message:	ILLEGAL ADDRESSING MODE
	Error description:	Illegal addressing mode in operand.
	Recovery procedure:	Correct the operand.
308	Message:	SYNTAX ERROR IN OPERAND
	Error description:	Syntax error in operand.
	Recovery procedure:	Correct the operand.
309	Message:	FLOATING POINT REGISTER MISMATCH
	Error description:	A double-precision floating-point register is specified for a single-precision operation or a single-precision floating-point register is specified for a double-precision operation.
	Recovery procedure:	Correct the operation size or the floating-point register.
DSP Instruction Errors		
350	Message:	SYNTAX ERROR IN SOURCE STATEMENT (<mnemonic>)
	Error description:	There are syntax error(s) in the DSP instruction statement.
	Recovery procedure:	Correct the source statement.

Table D-2 Source Program Error Messages (cont)

351	Message:	ILLEGAL COMBINATION OF MNEMONICS (<mnemonic>, <mnemonic>)
	Error description:	Illegal combination of DSP operation instruction is specified.
	Recovery procedure:	Correct the combination of DSP operation instructions.
352	Message:	ILLEGAL CONDITION (<mnemonic>)
	Error description:	Illegal condition for DSP operation instruction is specified.
	Recovery procedure:	Cancel the condition or change the DSP operation instruction.
353	Message:	ILLEGAL POSITION OF INSTRUCTION (<mnemonic>)
	Error description:	The DSP operation instruction is specified in an illegal position.
	Recovery procedure:	Specify the DSP operation instruction in the correct position.
354	Message:	ILLEGAL ADDRESSING MODE (<mnemonic>)
	Error description:	The addressing mode of the DSP operation instruction is illegal.
	Recovery procedure:	Correct the operand.
355	Message:	ILLEGAL REGISTER NAME (<mnemonic>)
	Error description:	The register name of the DSP operation instruction is illegal.
	Recovery procedure:	Correct the register name.
357	Message:	ILLEGAL COMBINATION OF MNEMONICS (<mnemonic>)
	Error description:	An illegal data move instruction is specified.
	Recovery procedure:	Correct the data move instruction.
371	Message:	ILLEGAL COMBINATION OF MNEMONICS (<mnemonic>, <mnemonic>)
	Error description:	The combination of data move instructions is illegal.
	Recovery procedure:	Correct the combination of data move instructions.
372	Message:	ILLEGAL ADDRESSING MODE (<mnemonic>)
	Error description:	An illegal addressing mode for the data move instruction operand is specified.
	Recovery procedure:	Correct the operand.
373	Message:	ILLEGAL REGISTER NAME (<mnemonic>)
	Error description:	An illegal register name for the data move instruction is specified.
	Recovery procedure:	Correct the register name.

Table D-2 Source Program Error Messages (cont)

Expression and Operation Errors		
400	Message:	CHARACTER CONSTANT TOO LONG
	Error description:	Character constant is longer than 4 characters.
	Recovery procedure:	Correct the character constant.
402	Message:	ILLEGAL VALUE IN OPERAND
	Error description:	Operand value out of range for this instruction.
	Recovery procedure:	Change the value.
403	Message:	ILLEGAL OPERATION FOR RELATIVE VALUE
	Error description:	Attempt to perform multiplication, division, or logic operation on relative value.
	Recovery procedure:	Correct the expression.
406	Message:	ILLEGAL OPERAND
	Error description:	An expression is specified at the location where floating-point data must be specified.
	Recovery procedure:	Specify floating-point data.
407	Message:	MEMORY OVERFLOW
	Error description:	Memory overflow during expression calculation.
	Recovery procedure:	Simplify the expression.
408	Message:	DIVISION BY ZERO
	Error description:	Attempt to divide by 0.
	Recovery procedure:	Correct the expression.
409	Message:	REGISTER IN EXPRESSION
	Error description:	Register name in expression.
	Recovery procedure:	Correct the expression.
411	Message:	INVALID STARTOF/SIZEOF OPERAND
	Error description:	STARTOF or SIZEOF specifies illegal section name.
	Recovery procedure:	Correct the section name.
412	Message:	ILLEGAL SYMBOL IN EXPRESSION
	Error description:	Relative value specified as shift value.
	Recovery procedure:	Correct the expression.
450	Message:	ILLEGAL DISPLACEMENT VALUE
	Error description:	Illegal displacement value. (Negative value is specified.)
	Recovery procedure:	Correct the displacement value.

Table D-2 Source Program Error Messages (cont)

452	Message:	ILLEGAL DATA AREA ADDRESS	
	Error description:	PC-relative data move instruction specifies illegal address for data area.	
	Recovery procedure:	Access a correct address according to the instruction operation size. (4-byte boundary for MOV.L and MOVA, and 2-byte boundary for MOV.W.)	
453	Message:	LITERAL POOL OVERFLOW	
	Error description:	More than 510 extended instructions exist that have not output literals.	
	Recovery procedure:	Output literal pools using .POOL.	
REPEAT Errors			
460	Message:	ILLEGAL SYMBOL	
	Error description:	A backward reference symbol, an undefined symbol, or a symbol other than a label is specified as an operand of a REPEAT, or the start address comes after (be at a higher address than) the end address.	
	Recovery procedure:	Correct the operand.	
461	Message:	SYNTAX ERROR IN OPERAND	
	Error description:	Illegal operand.	
	Recovery procedure:	Correct the operand.	
462	Message:	ILLEGAL VALUE IN OPERAND	
	Error description:	The distance between a REPEAT and the label exceeds the allowable range.	
	Recovery procedure:	Correct the location of the REPEAT or the label.	
463	Message:	NO INSTRUCTION IN REPEAT LOOP	
	Error description:	No instruction is found in a loop, or no instruction is found at the end address.	
	Recovery procedure:	Write an instruction between the start and end addresses, or specify an address storing an instruction as the end address.	
Assembler Directive Errors			
500	Message:	SYMBOL NOT FOUND	
	Error description:	Label not defined in directive that requires label.	
	Recovery procedure:	Insert a label.	

Table D-2 Source Program Error Messages (cont)

501	Message:	ILLEGAL ADDRESS VALUE IN OPERAND
	Error description:	Illegal specification of the start address or the value of location counter in section.
	Recovery procedure:	Correct the start address or value of location counter.
502	Message:	ILLEGAL SYMBOL IN OPERAND
	Error description:	Illegal value (forward reference symbol, import symbol, or relative address symbol) specified in operand.
	Recovery procedure:	Correct the operand.
503	Message:	UNDEFINED EXPORT SYMBOL
	Error description:	Symbol declared for export symbol not defined in the file.
	Recovery procedure:	Define the symbol. Alternatively, remove the export symbol declaration.
504	Message:	INVALID RELATIVE SYMBOL IN OPERAND
	Error description:	Illegal value (forward reference symbol or import symbol) specified in operand.
	Recovery procedure:	Correct the operand.
505	Message:	ILLEGAL OPERAND
	Error description:	Misspelled operand.
	Recovery procedure:	Correct the operand.
506	Message:	ILLEGAL OPERAND
	Error description:	Illegal element specified in operand.
	Recovery procedure:	Correct the operand.
508	Message:	ILLEGAL VALUE IN OPERAND
	Error description:	Operand value out of range for this directive.
	Recovery procedure:	Correct the operand.
510	Message:	ILLEGAL BOUNDARY VALUE
	Error description:	Illegal boundary alignment value.
	Recovery procedure:	Correct the boundary alignment value.
512	Message:	ILLEGAL EXECUTION START ADDRESS
	Error description:	Illegal execution start address.
	Recovery procedure:	Correct the execution start address.
513	Message:	ILLEGAL REGISTER NAME
	Error description:	Illegal register name.
	Recovery procedure:	Correct the register name.

Table D-2 Source Program Error Messages (cont)

514	Message:	INVALID EXPORT SYMBOL
	Error description:	Symbol declared for export symbol that cannot be exported.
	Recovery procedure:	Remove the declaration for the export symbol.
516	Message:	EXCLUSIVE DIRECTIVES
	Error description:	Inconsistent directive specification.
	Recovery procedure:	Check and correct all related directives.
517	Message:	INVALID VALUE IN OPERAND
	Error description:	Illegal value (forward reference symbol, an import symbol, or relative-address symbol) specified in operand.
	Recovery procedure:	Correct the operand.
518	Message:	INVALID IMPORT SYMBOL
	Error description:	Symbol declared for import defined in the file.
	Recovery procedure:	Remove the declaration for the import symbol.
520	Message:	ILLEGAL .CPU DIRECTIVE POSITION
	Error description:	.CPU is not specified at the beginning of the program, or specified more than once.
	Recovery procedure:	Specify .CPU at the beginning of the program once.
521	Message:	ILLEGAL .NOPOOL DIRECTIVE POSITION
	Error description:	.NOPOOL placed at illegal position.
	Recovery procedure:	Place .NOPOOL following a delayed branch instruction.
522	Message:	ILLEGAL .POOL DIRECTIVE POSITION
	Error description:	.POOL placed following a delayed branch instruction.
	Recovery procedure:	Place an executable instruction following the delayed branch instruction.
523	Message:	ILLEGAL OPERAND
	Error description:	Illegal .LINE directive operand.
	Recovery procedure:	Correct the operand.
525	Message:	ILLEGAL .LINE DIRECTIVE POSITION
	Error description:	.LINE directive specified during macro expansion or conditional iterated expansion.
	Recovery procedure:	Change the specified position of the .LINE directive.
File Inclusion, Conditional Assembly, and Macro Errors		
600	Message:	INVALID CHARACTER
	Error description:	Illegal character.
	Recovery procedure:	Correct it.

Table D-2 Source Program Error Messages (cont)

601	Message:	INVALID DELIMITER
	Error description:	Illegal delimiter character.
	Recovery procedure:	Correct it.
602	Message:	INVALID CHARACTER STRING FORMAT
	Error description:	Character string error.
	Recovery procedure:	Correct it.
603	Message:	SYNTAX ERROR IN SOURCE STATEMENT
	Error description:	Source statement syntax error.
	Recovery procedure:	Reexamine the entire source statement.
604	Message:	ILLEGAL SYMBOL IN OPERAND
	Error description:	Illegal operand specified in a directive.
	Recovery procedure:	No symbol or location counter ($) can be specified as an operand of this directive.
610	Message:	MULTIPLE MACRO NAMES
	Error description:	Macro name reused in macro definition (.MACRO directive).
	Recovery procedure:	Correct the macro name.
611	Message:	MACRO NAME NOT FOUND
	Error description:	Macro name not specified (.MACRO directive).
	Recovery procedure:	Specify a macro name in the name field of the .MACRO directive.
612	Message:	ILLEGAL MACRO NAME
	Error description:	Macro name error (.MACRO directive).
	Recovery procedure:	Correct the macro name.
613	Message:	ILLEGAL .MACRO DIRECTIVE POSITION
	Error description:	.MACRO directive appears in macro body (between .MACRO and .ENDM directives), between .AREPEAT and .AENDR directives, or between .AWHILE and .AENDW directives.
	Recovery procedure:	Remove the .MACRO directive.
614	Message:	MULTIPLE MACRO PARAMETERS
	Error description:	Identical formal parameters repeated in formal parameter declaration in macro definition (.MACRO directive).
	Recovery procedure:	Correct the formal parameters.
615	Message:	ILLEGAL .END DIRECTIVE POSITION
	Error description:	.END directive appears in macro body (between .MACRO and .ENDM directives).
	Recovery procedure:	Remove the .END directive.

Table D-2 Source Program Error Messages (cont)

616	Message:	MACRO DIRECTIVES MISMATCH
	Error description:	An .ENDM directive appears without a preceding .MACRO directive, or an .EXITM directive appears outside of a macro body (between .MACRO and .ENDM directives), outside of .AREPEAT and .AENDR directives, or outside of .AWHILE and .AENDW directives.
	Recovery procedure:	Remove the .ENDM or .EXITM directive.
618	Message:	MACRO EXPANSION TOO LONG
	Error description:	Line with over 255 characters generated by macro expansion.
	Recovery procedure:	Correct the definition or call so that the line is less than or equal to 255 characters.
619	Message:	ILLEGAL MACRO PARAMETER
	Error description:	Macro parameter name error in macro call, or error in formal parameter in a macro body (between .MACRO and .ENDM directives).
	Recovery procedure:	Correct the formal parameter.
	Supplement:	When there is an error in a formal parameter in a macro body, the error will be detected and flagged during macro expansion.
620	Message:	UNDEFINED PREPROCESSOR VARIABLE
	Error description:	Reference to an undefined preprocessor variable.
	Recovery procedure:	Define the preprocessor variable.
621	Message:	ILLEGAL .END DIRECTIVE POSITION
	Error description:	.END directive in macro expansion.
	Recovery procedure:	Remove the .END directive.
622	Message:	')' NOT FOUND
	Error description:	Matching parenthesis missing in macro processing exclusion.
	Recovery procedure:	Add the missing macro processing exclusion parenthesis.
623	Message:	SYNTAX ERROR IN STRING FUNCTION
	Error description:	Syntax error in character string manipulation function.
	Recovery procedure:	Correct the character string manipulation function.
624	Message:	MACRO PARAMETERS MISMATCH
	Error description:	Too many macro parameters for positional specification in macro call.
	Recovery procedure:	Correct the number of macro parameters.
631	Message:	END DIRECTIVE MISMATCH
	Error description:	Terminating preprocessor directive does not agree with matching directive.
	Recovery procedure:	Reexamine the preprocessor directives.

Table D-2 Source Program Error Messages (cont)

640	Message:	SYNTAX ERROR IN OPERAND
	Error description:	Syntax error in conditional assembly directive operand.
	Recovery procedure:	Reexamine the entire source statement.
641	Message:	INVALID RELATIONAL OPERATOR
	Error description:	Error in conditional assembly directive relational operator.
	Recovery procedure:	Correct the relational operator.
642	Message:	ILLEGAL .END DIRECTIVE POSITION
	Error description:	.END directive appears between .AREPEAT and .AENDR directives or between .AWHILE and .AENDW directives.
	Recovery procedure:	Remove the .END directive.
643	Message:	DIRECTIVE MISMATCH
	Error description:	.AENDR or .AENDW directive does not form a proper pair with .AREPEAT or .AWHILE directive.
	Recovery procedure:	Re-examine the preprocessor directives.
644	Message:	ILLEGAL .AENDW OR .AENDR DIRECTIVE POSITION
	Error description:	.AENDW or .AENDR directive appears between .AIF and .AENDI directives.
	Recovery procedure:	Remove the .AENDW or .AENDR directive.
645	Message:	EXPANSION TOO LONG
	Error description:	Line with over 255 characters generated by .AREPEAT or .AWHILE expansion.
	Recovery procedure:	Correct the .AREPEAT or .AWHILE to generate lines of less than or equal to 255 characters.
650	Message:	INVALID INCLUDE FILE
	Error description:	Error in .INCLUDE file name.
	Recovery procedure:	Correct the file name.
651	Message:	CANNOT OPEN INCLUDE FILE
	Error description:	Could not open .INCLUDE file.
	Recovery procedure:	Correct the file name.
652	Message:	INCLUDE NEST TOO DEEP
	Error description:	File inclusion nesting exceeded 30 levels.
	Recovery procedure:	Limit the nesting to 30 or fewer levels.

Table D-2 Source Program Error Messages (cont)

653	Message:	SYNTAX ERROR IN OPERAND
	Error description:	Syntax error in .INCLUDE operand.
	Recovery procedure:	Correct the operand.
660	Message:	.ENDM NOT FOUND
	Error description:	Missing .ENDM directive following .MACRO.
	Recovery procedure:	Insert an .ENDM directive.
662	Message:	ILLEGAL .END DIRECTIVE POSITION
	Error description:	.END directive appears between .AIF and .AENDI directives.
	Recovery procedure:	Remove the .END directive.
663	Message:	ILLEGAL .END DIRECTIVE POSITION
	Error description:	.END directive appears in included file.
	Recovery procedure:	Remove the .END directive.
664	Message:	ILLEGAL .END DIRECTIVE POSITION
	Error description:	.END directive appears between .AIF and .AENDI directives.
	Recovery procedure:	Remove the .END directive.
665	Message:	EXPANSION TOO LONG
	Error description:	Lines with over 255 characters are generated by the .DEFINE directive.
	Recovery procedure:	Correct the .DEFINE directive to generate lines of less than or equal to 255 characters.
667	Message:	SUCCESSFUL CONDITION .AERROR
	Error description:	Statement including the .AERROR directive was processed in the .AIF condition.
	Recovery procedure:	Correct the conditional statement so that the .AERROR directive is not processed.
668	Message:	ILLEGAL VALUE IN OPERAND
	Error description:	Error in the operand of the directive.
	Recovery procedure:	Specify, as the operand of this directive, a symbol defined by .DEFINE directive.

Table D-3 Source Program Warning Messages

DSP Instruction Warnings		
700	Message:	ILLEGAL VALUE IN OPERAND (<mnemonic>)
	Error description:	The operand value of the DSP operation instruction exceeds the specifiable range.
	Recovery procedure:	Correct the operand value within the specifiable range.
701	Message:	MULTIPLE REGISTER IN DESTINATION (<mnemonic>, <mnemonic>)
	Error description:	The same register is specified as multiple destination operands of the DSP instruction.
	Recovery procedure:	Specify the register correctly.
702	Message:	ILLEGAL OPERATION SIZE (<mnemonic>)
	Error description:	The operation size of the DSP operation instruction or the data transfer instruction is illegal.
	Recovery procedure:	Cancel or correct the operation size.
703	Message:	MULTIPLE REGISTER IN DESTINATION (<mnemonic>, <mnemonic>)
	Error description:	The same register is specified as the destination registers of the DSP operation instruction and data transfer instruction.
	Recovery procedure:	Specify the register correctly.
General Source Program Warnings		
800	Message:	SYMBOL NAME TOO LONG
	Error description:	A symbol exceeded 251 characters.
	Recovery procedure:	Correct the symbol.
	Supplement:	The assembler ignores the characters starting at the 252nd character.
801	Message:	MULTIPLE SYMBOLS
	Error description:	Symbol already defined.
	Recovery procedure:	Remove the symbol redefinition.
	Supplement:	The assembler ignores the second and later definitions.
807	Message:	ILLEGAL OPERATION SIZE
	Error description:	Illegal operation size.
	Recovery procedure:	Correct the operation size.
	Supplement:	The assembler ignores the incorrect operation size specification.

Table D-3 Source Program Warning Messages (cont)

808	Message:	ILLEGAL CONSTANT SIZE
	Error description:	Illegal notation of integer constant.
	Recovery procedure:	Correct the notation.
	Supplement:	The assembler may misinterpret the integer constant, i.e., interpret it as a value not intended by the programmer.
810	Message:	TOO MANY OPERANDS
	Error description:	Too many operands or illegal comment format.
	Recovery procedure:	Correct the operand or the comment.
	Supplement:	The assembler ignores the extra operands.
811	Message:	ILLEGAL SYMBOL DEFINITION
	Error description:	Specified label in assembler directive that cannot have a label.
	Recovery procedure:	Remove the label specification.
	Supplement:	The assembler ignores the label.
813	Message:	SECTION ATTRIBUTE MISMATCH
	Error description:	A different section type is specified on section restart (reentry), or, a section start address is respecified at the restart of absolute section.
	Recovery procedure:	Do not respecify the section type or start address on section reentry.
	Supplement:	The specification of starting section remains valid.
815	Message:	MULTIPLE MODULE NAMES
	Error description:	Respecification of object module name.
	Recovery procedure:	Specify the object module name once in a program.
	Supplement:	The assembler ignores the second and later object module name specifications.
816	Message:	ILLEGAL DATA AREA ADDRESS
	Error description:	Illegal allocation of data or data area.
	Recovery procedure:	Locate the word data or data area on an even address. Locate the long word or single-precision data or data area on an address of a multiple of 4. Locate the double-precision data or data area on an address of a multiple of 8.
	Supplement:	The assembler corrects the location of the data or data area according to its size.
817	Message:	ILLEGAL BOUNDARY VALUE
	Error description:	A boundary alignment value less than 4 specified for a code section.
	Recovery procedure:	The specification is valid, but if an executable instruction, DSP instruction, or extended instruction is located at an odd address, error 153 occurs.
	Supplement:	Special care must be taken when specifying 1 for code section boundary alignment value.

Table D-3 Source Program Warning Messages (cont)

818	Message:	COMMAND LINE OPTION MISMATCH FOR FLOATING DIRECTIVE
	Error description:	When the CPU type is SH-2E or SH-3E, the ROUND=NEAREST or DENORMALIZE=ON command line option is specified.
	Recovery procedure:	Change the specification in the ROUND or DENORMALIZE command line option.
	Supplement:	The assembler creates the object code according to the specification in the ROUND or DENORMALIZE command line option.
825	Message:	ILLEGAL INSTRUCTION IN DUMMY SECTION
	Error description:	An executable instruction, DSP instruction, extended instruction, or assembler directive that reserves data is in dummy section.
	Recovery procedure:	Remove, from the dummy section, the executable instruction, DSP instruction, extended instruction, or assembler directive that reserves data.
	Supplement:	The assembler ignores the executable instruction, DSP instruction, extended instruction, or assembler directive that reserves data in dummy section.
826	Message:	ILLEGAL PRECISION
	Error description:	The floating-point constant does not have the same precision specified with the operation size.
	Recovery procedure:	Correct the operation size or the precision type of the floating-point constant.
	Supplement:	The assembler assumes the precision specified with the operation size.
832	Message:	MULTIPLE 'P' DEFINITIONS
	Error description:	Symbol P already defined before a default section is used.
	Recovery procedure:	Do not define P as a symbol if a default section is used.
	Supplement:	The assembler regards P as the name of the default section, and ignores other definitions of the symbol P.
835	Message:	ILLEGAL VALUE IN OPERAND
	Error description:	Operand value out of range for this instruction.
	Recovery procedure:	Correct the value.
	Supplement:	The assembler generates object code with a value corrected to be within range.
836	Message:	ILLEGAL CONSTANT SIZE
	Error description:	Illegal notation of integer constant.
	Recovery procedure:	Correct the notation.
	Supplement:	The assembler may misinterpret the integer constant, i.e., interpret it as a value not intended by the programmer.

Table D-3 Source Program Warning Messages (cont)

837	Message:	SOURCE STATEMENT TOO LONG
	Error description:	The length of a source statement exceeded 255 bytes.
	Recovery procedure:	Rewrite the source statement to be within 255 bytes by, for example, rewriting the comment. Alternatively, rewrite the statement as a multi-line statement.
	Supplement:	The assembler ignores byte number 256, and regards the characters starting at byte 257 as the next statement.
838	Message:	ILLEGAL CHARACTER CODE
	Error description:	The shift JIS code or EUC code is specified outside character strings and comments, or the SJIS or EUC command line option is not specified.
	Recovery procedure:	Specify the shift JIS code or EUC code in character strings or comments. Specify the SJIS or EUC command line option.
839	Message:	ILLEGAL FIGURE IN OPERAND
	Error description:	Fixed-point data having six or more digits is specified in word size, or that having 11 or more digits is specified in long-word size.
	Recovery procedure:	Reduce the digits to the limit.
840	Message:	OPERAND OVERFLOW
	Error description:	Floating-point data overflows.
	Recovery procedure:	Modify the value.
	Supplement:	The assembler assumes + when the value is positive and – when negative.
841	Message:	OPERAND UNDERFLOW
	Error description:	Floating-point data underflows.
	Recovery procedure:	Modify the value.
	Supplement:	The assembler assumes +0 when the value is negative and –0 when negative.
842	Message:	OPERAND DENORMALIZED
	Error description:	Denormalized numbers are specified for floating-point data.
	Recovery procedure:	Check and correct the floating-point data.
	Supplement:	The assembler creates the object code according to the specification (sets denormalized numbers).
850	Message:	ILLEGAL SYMBOL DEFINITION
	Error description:	Symbol specified in label field.
	Recovery procedure:	Remove the symbol.

Table D-3 Source Program Warning Messages (cont)

851	Message:	MACRO SERIAL NUMBER OVERFLOW
	Error description:	Macro generation counter exceeded 99,999.
	Recovery procedure:	Reduce the number of macro calls.
852	Message:	UNNECESSARY CHARACTER
	Error description:	Characters appear after the operands.
	Recovery procedure:	Correct the operand(s).
854	Message:	.AWHILE ABORTED BY .ALIMIT
	Error description:	Expansion count has reached the maximum value specified by .ALIMIT directive, and expansion has been terminated.
	Recovery procedure:	Check the condition for iterated expansion.
870	Message:	ILLEGAL DISPLACEMENT VALUE
	Error description:	Illegal displacement value. (Either the displacement value is not an even number when the operation size is word, or the displacement value is not a multiple of 4 when the operation size is long word.)
	Recovery procedure:	Take account of the fact that the assembler corrects the displacement value.
	Supplement:	The assembler generates object code with the displacement corrected according to the operation size. (For a word size operation the assembler discards the low order bit of the displacement to create an even number, and for a long word size operation the assembler discards the two low order bits of the displacement to create a multiple of 4.)
871	Message:	PC RELATIVE IN DELAY SLOT
	Error description:	Executable instruction with PC relative addressing mode operand is located following delayed branch instruction.
	Recovery procedure:	Take account of the fact that the value of PC is changed by a delayed branch instruction.
	Supplement:	The assembler generates object code exactly as specified in the program.
874	Message:	CANNOT CHECK DATA AREA BOUNDARY
	Error description:	Cannot check data area boundary for PC-relative data move instructions.
	Recovery procedure:	Note carefully the data area boundary at linkage process.
	Supplement:	The assembler only outputs this message when a data move instruction is included in a relative section, or when an import symbol is used to indicate a data area.

Table D-3 Source Program Warning Messages (cont)

875	Message:	CANNOT CHECK DISPLACEMENT SIZE
	Error description:	Cannot check displacement size for PC-relative data move instructions.
	Recovery procedure:	Note carefully the distance between data move instructions and data area at linkage.
	Supplement:	The assembler only outputs this message when a data move instruction is included in a relative section, or when an import symbol is used to indicate a data area.
876	Message:	ASSEMBLER OUTPUTS BRA INSTRUCTION
	Error description:	The assembler automatically outputs a BRA instruction.
	Recovery procedure:	Specify a literal pool output position using .POOL, or check that the program to which a BRA instruction is added can run normally.
	Supplement:	When a literal pool output location is not available, the assembler automatically outputs literal pool and a BRA instruction to jump over the literal pool.
880	Message:	END NOT FOUND
	Error description:	No .END in the program.
	Recovery procedure:	Add an .END.
881	Message:	ILLEGAL DIRECTIVE IN REPEAT LOOP
	Error description:	An illegal assembler directive was found in a loop.
	Recovery procedure:	Delete the directive.
	Supplement:	If a directive that reserves a data item or a data area, an .ALIGN directive, or an .ORG directive is used in a loop, the assembler counts the directive as one of the instructions to be repeated.

Table D-4 Fatal Error Messages

Fatal Errors		
901	Message:	SOURCE FILE INPUT ERROR
	Error description:	Source file input error.
	Recovery procedure:	Check the hard disk for adequate free space. Create the required free space by deleting unnecessary files.
902	Message:	MEMORY OVERFLOW
	Error description:	Insufficient memory. (Unable to process the temporary information.)
	Recovery procedure:	Subdivide the program.
903	Message:	LISTING FILE OUTPUT ERROR
	Error description:	Output error on the list file.
	Recovery procedure:	Check the hard disk for adequate free space. Create the required free space by deleting unnecessary files.
904	Message:	OBJECT FILE OUTPUT ERROR
	Error description:	Output error on the object file.
	Recovery procedure:	Check the hard disk for adequate free space. Create the required free space by deleting unnecessary files.
905	Message:	MEMORY OVERFLOW
	Error description:	Insufficient memory. (Unable to process the line information.)
	Recovery procedure:	Subdivide the program.
906	Message:	MEMORY OVERFLOW
	Error description:	Insufficient memory. (Unable to process the symbol information.)
	Recovery procedure:	Subdivide the program.
907	Message:	MEMORY OVERFLOW
	Error description:	Insufficient memory. (Unable to process the section information.)
	Recovery procedure:	Subdivide the program.
908	Message:	SECTION OVERFLOW
	Error description:	The number of sections exceeded 65,535.
	Recovery procedure:	Subdivide the program.
909	Message:	SYMBOL OVERFLOW
	Error description:	The number of symbols exceeded 65,535.
	Recovery procedure:	Subdivide the program.
910	Message:	SOURCE LINE NUMBER OVERFLOW
	Error description:	The number of source program lines exceeded 65,535.
	Recovery procedure:	Subdivide the program.

Table D-4 Fatal Error Messages (cont)

911	Message:	IMPORT SYMBOL OVERFLOW
	Error description:	The number of import symbols exceeded 65,535.
	Recovery procedure:	Reduce the number of import symbols.
912	Message:	EXPORT SYMBOL OVERFLOW
	Error description:	The number of export symbols exceeded 65,535.
	Recovery procedure:	Reduce the number of export symbols.
933	Message:	ILLEGAL ENVIRONMENT VARIABLE
	Error description:	The specified target CPU is incorrect.
	Recovery procedure:	Correct the target CPU.
935	Message:	SUBCOMMAND FILE INPUT ERROR
	Error description:	Subcommand file input error.
	Recovery procedure:	Check the hard disk for adequate free space. Create the required free space by deleting unnecessary files.
936	Message:	SUPPLEMENT FILE OUTPUT ERROR
	Error description:	Supplement file output error.
	Recovery procedure:	Check the hard disk for adequate free space. Create the required free space by deleting unnecessary files.
950	Message:	MEMORY OVERFLOW
	Error description:	Insufficient memory.
	Recovery procedure:	Separate the source program.
951	Message:	LITERAL POOL OVERFLOW
	Error description:	More than 100,000 internal symbols are used for literal pools.
	Recovery procedure:	Separate the source program.
952	Message:	LITERAL POOL OVERFLOW
	Error description:	Literal pool capacity overflow.
	Recovery procedure:	Insert unconditional branch before overflow.
953	Message:	MEMORY OVERFLOW
	Error description:	Insufficient memory.
	Recovery procedure:	Separate the source program.
954	Message:	LOCAL BLOCK NUMBER OVERFLOW
	Error description:	The number of local blocks that are valid in the local label exceeded 100,000.
	Recovery procedure:	Separate the source program.

Table D-4 Fatal Error Messages (cont)

956	Message:	EXPAND FILE INPUT/OUTPUT ERROR
	Error description:	File output error for preprocessor expansion.
	Recovery procedure:	Check the hard disk for adequate free space. Create the required free space by deleting unnecessary files.
957	Message:	MEMORY OVERFLOW
	Error description:	Insufficient memory.
	Recovery procedure:	Separate the source program.
958	Message:	MEMORY OVERFLOW
	Error description:	Insufficient memory.
	Recovery procedure:	Separate the source program.

Appendix E Differences from Version 3.1

The differences between this new version (V.4.0) and the former version (V.3.1) are described below.

E.1 CPU

This version includes assembly functions for the SH-2E, SH-4, and SH3-DSP in addition to the SH-1, SH-2, SH-3, SH-3E, and SH-DSP, and the following items are added or changed.

- Reserved words
- Executable instructions
- .CPU assembler directive
- CPU command line option
- SHCPU environment variable

References:

Reserved words
→ Programmer's Guide, 1.2, "Reserved Words"
Executable instructions
→ Programmer's Guide, 3, "Executable Instructions"
.CPU assembler directive
→ Programmer's Guide, 5.2.1, "Assembler Directive Related to CPU"
–CPU command line option
→ User's Guide, 2.2.1, "Target CPU Command Line Option"
SHCPU environment variable
→ User's Guide, 1.3, "SHCPU Environment Variable"

E.2 Object Format

In the new version, ELF/DWARF object format is supported in addition to those supported in the former version.

The assembler outputs ELF/DWARF supplement information when outputting debug information.

References:

Debug information
→ Programmer's Guide, 5.2.6, "Object Module Assembler Directives", .OUTPUT
→ User's Guide, 2.2.2, "Object Module Command Line Options", –DEBUG

E.3 Constants

In the new version, double-precision floating-point constants can be used in addition to single-precision floating-point constants.

- Double-precision floating-point constants are used in the SH-4.

Reference:

Floating-point constants
→ Programmer's Guide, 1.4.3, "Floating-Point Constants"

E.4 Changed Assembler Directives

Table E-1 lists the double-precision registers and operation sizes added to assembler directives and assembler statements related to floating-point constants in the new version.

Table E-1 Changed Assembler Directives and Statements

Assembler Directive or Statement	Function	Reference in Programmer's Guide
.FREG	Floating-point register types	5.2.3
.FDATA	Double-precision operation size	5.2.4
.FDATAB	Double-precision operation size	5.2.4
.FRES	Double-precision operation size	5.2.4

E.5 Added Command Line Options

Table E-2 lists the command line options added to the new version.

Table E-2 Added Command Line Options

Command Line Option	Function	Reference in User's Guide
ROUND	Selection of floating-point data rounding mode	2.2.10
DENORMALIZE	Selection of how to handle denormalized numbers in floating-point data	2.2.10

Reference:

Floating-point constants
→ Programmer's Guide, 1.4.3, "Floating-Point Constants"

Appendix F ASCII Code Table

Table F-1 ASCII Code Table

	Upper 4 Bits							
Lower 4 Bits	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
0	NUL	DLE	SP	0	@	P	`	p
1	SOH	DC1	!	1	A	Q	a	q
2	STX	DC2	”	2	B	R	b	r
3	ETX	DC3	#	3	C	S	c	s
4	EOT	DC4	$	4	D	T	d	t
5	ENQ	NAK	%	5	E	U	e	u
6	ACK	SYN	&	6	F	V	f	v
7	BEL	ETB	’	7	G	W	g	w
8	BS	CAN	(	8	H	X	h	x
9	HT	EM	)	9	I	Y	i	y
A	LF	SUB	*	:	J	Z	j	z
B	VT	ESC	+	;	K	[	k	{
C	FF	FS	,	<	L	\	l	|
D	CR	GS	–	=	M	]	m	}
E	SO	RS	.	>	N	^	n	~
F	SI	US	/	?	O	_	o	DEL

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